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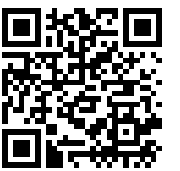

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OF

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FIELD SKETCHING.

1921.

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MANUAL OF MAP READING AND FIELD SKETCHING.

CHAPTER I.

INTRODUCTION.

§1. Purpose and Standard of Instruction.

1. *Purpose of the Manual.*—This manual is intended for the use of candidates for commissions in the regular army, cadets of the Royal Military Academy, of the Royal Military College and of the Royal Air Force Cadet College, and for the instruction of officers and non-commissioned officers. Its object is to provide full instruction in map reading, in the use of maps, in the employment of simple field instruments and in making sketches for military purposes. It is not intended to teach the methods of construction of an accurate map, which is the work of the trained surveyor.

2. *Standard required.*—All officers and non-commissioned officers must be trained to be proficient in map reading. All officers, and a proportion of non-commissioned officers, should in addition be capable of adding topographical information to an existing map, or to an enlargement, and of making a simple military sketch.

Officers who show special aptitude should be given opportunities to improve themselves in sketching.

§2. Arrangement and Enlargement of Manual.

3. *Division of Manual.*—The manual is divided into two parts and appendices.

Part I treats of Map Reading. This part, besides instruction in the use and meaning of scales, conventional signs and the various methods of representing topographical features, gives some account of the various maps of the British Empire and of others likely to be met with on active service. It also deals with the important questions of squared and gridded maps. Part I contains all that is essential to the training of non-commissioned officers.

Part II deals with Military Sketching. After a short preliminary note on the principles of surveying, a full description is given

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of sketching with the plane table, with the prismatic compass and with the cavalry sketching board. Chapters are devoted to panorama drawing, to air photographs, and to military reports. Instruction is given in methods of enlarging maps, and in adding extra information to a map. Field methods are given for finding true north and for marching by night.

In Parts I and II, it will be seen that portions of the text are in small type. These portions, unless when they refer to examples illustrative of the text, may, if desired, be omitted on the first reading of the manual, and reserved until the student is more familiar with the subject.

The appendices are confined to subjects which may be required for reference, or which the advanced student may desire to study. They include lists of maps, notes on map projection and land forms and the proper method of spelling foreign names.

4. *Reasons for Additions.*—It will be found that this edition of the manual contains a good deal more material than previous editions, and it is desirable to explain the reasons for this. Generally speaking, it is due to the advance of knowledge and the increased complication of modern warfare, which must of necessity make greater demands on the officers and soldiers of an efficient army.

The manual now contains much fuller instruction on the subject of plane-table sketching than has hitherto appeared in any other official publication. It is not intended that every officer shall become a skilled plane-tabler, but it is desired that the officer who wishes to make himself proficient in that art shall find in this manual the full means whereby he may do so, without recourse to scattered and diverse publications. It may also be observed that the officer who becomes a proficient plane-tabler, even though he may never find occasion to use a plane table on service, will undoubtedly, owing to his knowledge, be a much quicker and more accurate military sketcher, whether with the prismatic compass, the cavalry sketching board or any improvised method. The short sketch of the principles of survey is included with a similar object, to enable the intelligent and enquiring officer or soldier to understand the broad principles on which all map making is based.

The subject of squared maps and the kindred subject of gridded maps—the distinction is important and should be noted—are new and the outcome of war experience. Their inclusion is necessary, because a proper understanding of these questions is now an essential part of military education.

No manual dealing with maps and topography would now be complete without a reference to air photographs. A short chapter has therefore been added dealing with the elements of this important subject.

Certain other matters have been treated more fully than before, either because previous instruction was lacking or because of the increased requirements of recent warfare.

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PART I.

CHAPTER II.

DEFINITIONS.

§3. Topographical Forms.

Of the topographical terms which abound in English, only those considered of rather more than ordinary military importance are here defined.

Basin: A term used to describe (*a*) a small area of fairly level ground, surrounded or nearly surrounded by hills; and (*b*) a district drained by a river and its tributaries, as the "basin of the Thames."

Bluff: A broad precipitous ending of a headland, hillside, spur or buttress, usually abutting on a river, coast or valley.

Brow, sometimes termed *military crest*: The edge beneath the crest of a ridge, hill or mountain, at which a gentle upper slope changes to a longer and steeper lower slope; at the top of the lower main slope the high line which follows the shoulder of a mountain, range or plateau, and which commands the foot or foothills.

Buttress (French *Contrefort*): A short spur flanking a range, main spur or hill.

Col or *Saddle*: A depression between two contiguous mountains or hills; or a break in a ridge; or a short neck of land connecting a high outlying feature with a chain of mountains or range of hills, or with a main spur.

Coomb: The upper part of a valley when its head is deeply cut in a hillside. In Wales the *Cwm* is ordinarily high and, like the *Corry* in Scotland, may be defined as a steep-sided hollow in a mountain side with a U-shaped cross-section.

Crest: The spinal tract of a chain, ridge or spur; or the continuous strip of top, commonly narrow, between the final ascents from either side to the ridge-line.

The crest is sometimes practically equivalent to the ridge-line (*q.v.*); but whereas the latter is considered a definite line, the former has at least some width.

Defile: A long narrow pass through hills.

Delta: Where a river has more than one mouth, the triangle of level country within the extreme outflows on either side.

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Divide: Applied to the line of actual water-parting on a major watershed.

The *Divide* or *Ridge-line* is one of the three *Characteristic Lines*, that is to say, principal feature-lines of the topography. The other two Characteristic Lines are the *Valley-line* and the *Brow*.

Escarpment or *Scarp*: The wall of a plateau; an *extended* line of high cliff.

Estuary: The tidal ending of a river.

Gorge: A deep and steep-sided valley, the floor of which is narrow and of gentle gradient and usually occupied by a river.

Gully (*Gulch*): The upper portion of a ravine where it rises to the headwater of the contained stream.

Knoll: A low detached hill.

Massif: An integral mountain mass, often ending in a peak, considered apart from connecting plateaus or chains.

Morass: An impassable swamp; an extensive quagmire.

Plateau: An elevated plain.

Prominence: An outstanding hill feature arising above the ordinary line of crest of a range or chain.

It may be a *Peak*, *Dome*, *Hogsback*, *Stack*, *Cone* or *Pinnacle*.

Ravine: The upper portion of a steep-sided valley, the bottom of which is narrow and of considerable gradient, usually containing a mountain stream.

Re-entrant: The shallow penetration of a plain into a hill feature.

Ridge-line: Applied to the line of actual water-parting on minor watersheds. See *Divide*.

Saddle: See *Col*.

Salient: The projection into a plain of a minor buttress.

Spur: A projection from the side of a hill, running out from the main feature; or a secondary range running out from a mountain chain or plateau.

Underfeature: A minor feature; an offshoot of a main hill feature; a foot-hill almost detached from the range.

Watershed: A ridge of high land separating two drainage basins; or the summit of comparatively low land from which water divides or flows in two directions.

A watershed does not necessarily include the *highest points* of a chain of mountains or range of hills. The term in topography ought not to be applied to the *slopes* of the basins, though it is often so applied by engineers.

Valley-line (*Thalweg*): The line, usually sinuous, defining the lowest part of a valley, down which water flows if a watercourse exists.

The Valley-line need not follow the stream in its extreme meandering through a plain. The German term "thalweg" is interesting and important because it has been commonly used in international treaties to

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define the exact line in a watercourse which defines the boundary of a frontier. In this usage it is the equivalent of the English word *channel*, since it follows the stream throughout, even in extreme meandering. When the stream has two branches, the word channel is properly applied to the deeper or more navigable.

§4. Technical Terms.

Axes of Grid: Two straight lines, one running N. and S., the other E. and W., crossing at a certain chosen point in the country.

The chosen point is named the *origin*, since to it are referred, by means of *rectangular co-ordinates* measured on the map parallel to the axes, the positions of all points of any importance in the country.

Azimuth: See *True Bearing.*

Bearing:

(1) In general.—The angle, measured clockwise, from a certain fixed line to any line in question.

(2) *True Bearing* or *Azimuth.*—The fixed line in this case is the line of direction of *True North.*

(3) *Grid Bearing.*—The fixed line here is that of *Grid North.*

(4) *Magnetic Bearing.*—The fixed line is that of *Magnetic North.*

The following expressions are used in *Traverse Surveying*:

(5) *Forward Bearing.**—The forward *direction* or *bearing* of the forward station next in succession in a traverse.

(6) *Back Bearing.**—The rearward direction or bearing of the next preceding station in a traverse.

The *angle* of a traverse is the difference between these two bearings, measured in the sense Forward *minus* Backward.

(7) *Closing Bearing.**—The bearing taken from the last station in a traverse to some fixed point, which sometimes is the initial station, to ascertain the error of direction of the closing line.

Contour: The representation of an imaginary line running along the surface of the ground at the same height above mean-sea-level throughout its length. Contours may also be defined as the traces of the lines at which a water surface (of the ocean, for instance) would intersect the irregular surface of the earth were the water to rise successively by equal amounts.

Conventional Sign Sheet: An index sheet showing the *Conventional Signs, Types of Lettering, Colour Scheme, Abbreviations,* &c., used on maps of a given category.

Convergence of Meridians: The inclination of the direction of a meridian at one point to that of another meridian at another

* The terms *Forward Angle*, &c., were formerly used, but *Bearing* is preferable.

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point. One of these meridians containing the origin being the N.—S. axis of the grid, to which all grid north lines are parallel, the angle between the axis and the direction of the meridian of any point A, that is to say, the convergence at A, is in practice the angle between the grid north line through A and the meridian of A.

Co-ordinates: Distances measured, usually east and north, from the origin of a grid system, to define the position of a point.

The northerly co-ordinate is sometimes called the Y-co-ordinate; the easterly the X-co-ordinate. These co-ordinates are rectilinear and rectangular. Co-ordinates may also be curvilinear, as, for example, latitude and longitude, which are generally described as *geographical co-ordinates.*

Datum or *Datum-Level*: An assumed level surface to which altitudes are referred.

Dip of the Compass: The "Inclination" or depression from the horizontal when the needle is free to move in a vertical plane.

Equator: The circle at 90° from either pole. It cuts all the *meridians* at right angles and divides the earth into two equal parts, named the Northern and Southern Hemispheres.

Fall of a river: Its slope, usually measured in inches (or feet) per mile.

Form-line: An approximate contour.

Gradient or Slope: A rate of rise or fall, expressed by a fraction. Thus 1/30 represents a slope of 1 foot in 30 feet horizontal.

Graticule: The network formed on a map by the lines of meridian and parallel.

Grid: The representation on a map of a rectangular co-ordinate system.

NOTE: A grid system is to be distinguished from a mere system of squares into which a map may be parcelled out for purposes of reference. A grid system is based on a definite point as origin of the co-ordinates, on a definite line which fixes the orientation, and on a definite form of projection. It refers to an area, not to a map.

Grid North: The vertical line at any point in a grid system. This line is taken as the zero of the *grid bearing;* in other words, as the working north-line to which the grid bearings of other lines from the point are referred.

Grid North is the same as *True North* on the meridian of the origin only. The deviation increases with the distance E. or W. from this meridian, and is a measure of the *Convergence of Meridians.*

Hachures: Hachuring is a conventional method of representing hill features by shading in short disconnected lines drawn directly down the slopes in the directions in which water would flow; hachures thus follow the lines of greatest slope.

Horizontal Equivalent—usually written *H.E.*: The distance in plan between two adjacent contours.

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Intersection: A principle of survey, whereby objects are fixed by the observation of rays or bearings to them from two or more previously fixed points.

Intersected Point: A position not visited by the observer, but fixed by angular measures made to it from two or more occupied and previously fixed points.

Latitude: The latitude of a place is the arc of the *meridian* from the place to the equator, expressed in degrees at the centre of the earth.

Local Magnetic Attraction.—The deviation of the magnetic needle of a compass from its true position owing to the presence of magnetic iron-ore, of iron, nickel or cobalt in the neighbourhood.

Longitude: The longitude of a place is the arc of the *equator* between the meridian of the place and the meridian which passes through a certain spot in Greenwich Observatory. The arc of the equator is expressed in degrees at the earth's centre.

International longitude is measured East or West of the *Prime Meridian* of Greenwich; but, particularly on maps of older date, many other prime meridians have been used, *e.g.*, those of Ferro, Paris, Constantinople, &c.

Magnetic Meridian: A magnetic north and south line.

Magnetic Variation: The deviation of the compass from true north; in other words, the angle between true north and magnetic north. The variation is named E. or W. according as the magnetic needle points East or West of True North.

The term "declination" is used by scientists instead of *Variation*.
The variation changes from year to year; this is called the *Annual Change*.

Meridian: A true north and south line; hence a great circle passing through both poles and cutting the equator at right angles.

Orienting or Setting a map or plane-table is the process of placing the map or plane-table so that the north line on the sheet points north.

Origin: The *true origin* is the crossing of the fundamental axes of a grid system; hence it is the point on the earth's surface to which the rectangular co-ordinates of a grid system are primarily referred.

The published co-ordinates are now usually referred to a *false origin*, some distance to the S.W. of the true origin.

Parallel of Latitude: A circle on the earth's surface parallel to the equator, and hence of equal latitude throughout.

Planimetry: (1) Measurement in a horizontal plane; (2) the plan detail plotted on a map from the results of such measurement.

Plotting: The process of laying down on paper field observations and measurements.

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Profile: See *Section.*

Projection is the name given to methods of representing the convex surface of the earth on a plane surface, such as a map.

Ray: A line drawn to represent the direction of an object without reference to the points of the compass.

Representative Fraction—usually written *R.F.*: The ratio which the actual length between any two points on a map bears to the distance between the same two points on the ground.

The distances must be reduced to the same unit, and the ratio is always expressed as a fraction of which the numerator is 1.

Resection.—A principle of survey, whereby an observer fixes the position of his standpoint by observing to at least two previously fixed points, not themselves occupied for this purpose.

Resected Point: A position fixed by resection, commonly by measures of two angles subtended by three fixed points.

Section or Profile: The outline of the intersection of the surface of the ground by a vertical plane.

Slope: See *Gradient.*

Spot Height: The record on a map of the exact height of a particular point.

Squared Maps are those parcelled out regularly into squares for the sake of reference.

A squared map is not necessarily a gridded map, because the squares may be drawn without regard to any particular system, and may have no connection with the squares on an adjoining sheet. The essence of a gridded map, on the other hand, is that the squares are drawn on a regular system which is continuous over a large area, irrespective of sheet lines.

Traverse: The survey of a road, river or track by measuring the lengths of a continuous series of straight lines along its course, together with the angles at their junctions.

Triangulation: A principle of survey, involving the process of fixing the positions of points by means of a measured base and, dependent thereon, a network of triangles whose angles are measured.

Trig Point: A well-marked position fixed by triangulation.

Variation: See *Magnetic Variation.*

Vertical Interval—usually written *V.I.*: The difference in level between two successive contours.

These lists do not profess to be exhaustive of terms of military importance; there are many topographical and technical terms, particularly the former, of which the meaning and application are too well known to require definition.

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Chapter III.

SCALES AND THEIR CONSTRUCTION.

§5. Scale, R.F., and Unit of Measure.

5. *Scale.*—The word *scale* is used to denote the proportion which the length between any two points on a map or sketch bears to the horizontal distance between the same two points on the ground. Thus, if the length between two farmhouses measures one inch on the map and the horizontal distance over the ground measures two miles, the scale of the map is 1 inch to 2 miles. Similarly the statement that a map is on a scale of 1/250,000* implies that a length of 1 inch on the map represents an actual distance of 250,000 inches, *i.e.*, 3·95 miles. One may then say either that the scale of this map is 1 inch to 3·95 miles, or that the scale is 1/250,000. The latter is termed the *Representative Fraction.*

6. *Representative Fraction.*—From the statement above, it is clear that the Representative Fraction, commonly written *R.F.*, follows at once from the expression of corresponding distances on the map and on the earth's surface in the same *unit.* This unit may be any linear standard, *e.g.*, an inch, a foot or a yard ; a millimetre, a centimetre or a metre.

There are therefore two ways of describing the scale of a map : in the first, the relation of map measure to ground measure is expressed in words and in different units, whereas in the second it is expressed in terms of a fraction with 1 as numerator, the unit in the latter case being immaterial ; hence the R.F. was formerly known as the *Natural Scale.*

7. *Examples of Conversion.*—The following examples explain the two methods of expressing scales :—

(i) Scale 1/63,360 or 1 inch to 1 mile. Here 1 inch on the map represents on the ground 63,360 inches, *i.e.*, 1 mile.

(ii) Scale 1/100,000, or 1 centimetre to 1 kilometre. Here 1 inch on the map represents on the ground 100,000 inches = 1·58 miles ; or 1 centimetre on the map represents on the ground 100,000 cms. = 1,000 metres = 1 kilometre.

The converse problem, to determine an expression for the scale

* This method of writing a fraction is in comm n use now, and is often more convenient than the old form $\frac{1}{250000}$.

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in British units when the R.F. is given, is solved by the following two rules :—

(1) To find the number of English miles on the ground corresponding to 1 inch on a map for which the R.F. is given, divide the denominator of the R.F. by 63,360.

(2) To find the number of inches on the map corresponding to 1 mile on the ground, divide 63,360 by the denominator of the R.F.

Thus, if the R.F. is 1/80,000, by rule (1) the number of miles to the inch is $80,000/63,360 = 1 \cdot 26$. And by (2) the scale in inches to 1 mile is $63,360/80,000 = 0 \cdot 79$.

It is useful to remember that an R.F. of 1/1,000,000, commonly written 1/M, is equivalent to $15 \cdot 78$ (or approximately 16) miles to an inch. A comparison then tells us at once that 1/250,000 is about 4 miles to an inch ; 1/2M is about 32 miles to 1 inch ; and so on.

8. *Colloquial Description.*—Large-scale maps are often mentioned colloquially with reference to a ground unit of 1 mile ; thus the " six-inch " and " half-inch " of the United Kingdom are respectively 6 inches and $\frac{1}{2}$-inch to 1 mile. On the other hand, the small-scale maps are sometimes described in terms of a fixed map unit of 1 inch ; thus the " 10-mile map " has a scale of 1 inch to 10 miles; *i.e.*, the R.F. is 1/633,600.

9. *Comparison of the two Ways of stating Scale.*—Of the two methods of indicating the scale of a map—by verbal description in different units and by the R.F.—each has its advantages. The first has the more important advantage that, if the eye has once been trained to visualize the length of an inch or a centimetre, it can readily estimate the distance between any two mapped features. On the other hand, the true relation between maps which employ different units can be at once established by means of the R.F. The R.F. therefore is, or should be, given on every map.

10. *Unit of Measure.*—A scale is always constructed to show distances in a certain unit, be it a foot, a yard or a mile, a metre or a kilometre, a verst or some other measure. This is known as the *unit of measure*, and is, or ought to be, always written on the scale. Thus we speak of " a scale of 1/2,500 showing yards," the yard in this case being the unit of measure. The smallest distance actually cut on a scale will often be a multiple of ten of such units, such as 100 feet, 20 yards, 10 kilometres. It is common to find the same scale in two units in juxtaposition; thus one may have a scale of 1/20,000 showing yards and miles, the yard graduation being perhaps below and the mileage above the scale-line.

§6. Division and Construction of Scales.

11. *Division and Length of Scales.*—Scales are technically described as of two kinds—*fully-divided* and *open-divided.* In the

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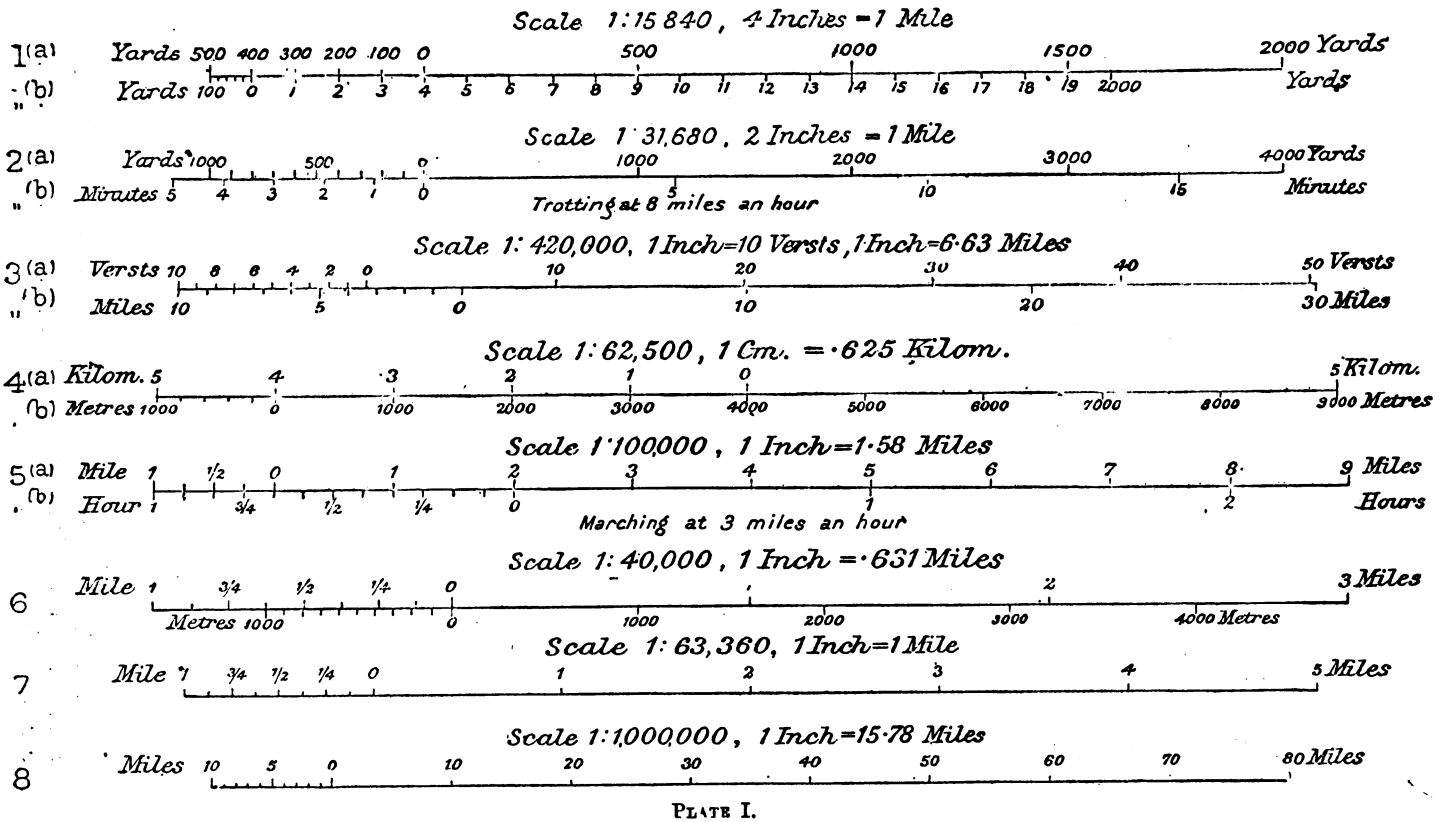

PLATE I.

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fully-divided scale the smaller divisions, known as the *secondary divisions*, are cut throughout the whole length of the scale; whereas in the open-divided scale the smaller divisions are confined to the space between one of the large or *primary divisions*. In the fully-divided scale the zero is placed at the extreme left; in the open-divided scale, on the other hand, the secondary division is always (or should be) an extension backwards from the zero of the primary scale, the secondary scale therefore being read from the zero towards the left. (*See* Plate I.) Moreover the length of this secondary division should be equal to one space of the primary division and should be fully graduated.

The open-divided scale is the type usually found on maps.

Scales are usually, though not necessarily, constructed of such a length as to represent a distance which is a multiple of 10 or 100 units of measure; thus, if the unit of measure be a mile, the scale may show up to 10, or 50, or 80 miles, or some such distance; if the unit of measure be the yard, its total length may represent 1,000, 5,000, 10,000, 40,000 yards or some such distance.

A scale for map reading in the field or for field sketching should be about 6 inches long.

12. *Division of (i) Sketching Scales.*—The following are general rules for the selection of primary and secondary divisions for scales used in field sketching:—

(1) The primary division of a scale of miles or kilometres should be the single mile or kilometre.

(2) A scale of yards or metres should show primaries differing according to the R.F. of the scale to be used: the primary ought to be 1,000 yards or metres for scales up to 1/31,680 ("2-inch"), and 500 yards or metres for larger scales.

(3) Secondary divisions on a scale of miles or kilometres should represent $\frac{1}{8}$-mile or $\frac{1}{5}$-kilometre; on a scale of yards or metres, the spaces should correspond to 100 yards or metres. *See* Plate I, Scales 1 (*a*) and 2 (*a*).

These rules apply to military sketches, which can rarely be of sufficient accuracy to make it necessary to indicate smaller secondaries.

13. *Division of (ii) Map Scales.*—The rules for map scales are different, and as map scales are necessarily cut on the Service Protractor (Plate XV), the latter may be consulted. On these scales the primaries are groups of miles, yards, &c. (say, 10, 20, 50, 100) chosen according to the scale of the map. In general for map scales the secondaries are cut as close as is consistent with legibility in a poor light; one-fiftieth of an inch or one-half of a millimetre is a limit of division which ought not to be exceeded. The smallest ground length in metres that can then be shown on a scale is found by dividing the denominator of the R.F. by 2,000.

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14. *Construction of Scales.*—We now come to the actual construction of scales and shall give some examples :—

Ex. 1.—*To construct a sketching scale of* 4 *inches to* 1 *mile to show divisions of* 100 *yards.*

Here 4 inches represents 1 mile, or 63,360 inches. The R.F. is therefore 4/63,360 = 1/15,840.

The scale is to be between 4 and 6 inches in length; it will therefore show between 1 and 1½ miles, say between 1,800 and 2,600 yards. Take the greatest round number between these limits, say 2,500 yards.

The length of the scale will then be

$$\frac{2{,}500}{15{,}840}\text{yards} = \frac{2{,}500 \times 36}{15{,}840}\text{inches} = 5{\cdot}68 \text{ inches.}$$

If it is preferred the result may be obtained from a sum in proportion, thus :—

Yards in a mile.		Yards in the scale.		Inches representing a mile.		Length of scale in inches.
1,760	:	2,500	=	4	:	5 68

The length of a scale should be calculated to the second decimal of an inch or the first of a millimetre.

Draw a line 5·68 inches long and divide it into 5 equal parts, each representing 500 yards. Sub-divide the left division into 5 parts, each representing 100 yards, as shown in Plate I, Scale I (*a*).

Ex. 2.—*To construct a scale of* 2 *inches to a mile to show hundreds of yards.*

In this case 5,000 yards, being nearly 3 miles, will clearly be represented by a length of nearly 6 inches.

The R.F. = 2/63,360 = 1/31,680, and the length of the scale will be 5,000 × 36/31,680 = 5·68 inches.

The primaries by rule are to represent 1,000 yards. Draw then a line 5·68 inches long and divide it into 5 equal parts, each of 1·14 inch. Mark these parts : Yards 1,000, 0, 1,000, 2,000, 3,000, 4,000 Yards.

For the secondary division, of 100 yards by rule, divide the left-hand primary into 10 parts (each 0·114 inch), to be read from the zero increasing towards the left. But as there is barely room for so many figures, number the 500 division alone, as in Plate I, Scale 2 (*a*).

Ex. 3.—*To construct a scale of* 1/100,000 *to show quarter miles.*

Here 1 mile is represented by 1/100,000 mile = 63,360/100,000 inch = 0·634 inch. Hence, if the scale is to represent 10 miles in all, its total length will be 6·34 inches.

With the dividers bisect the total length of 6·34 inches, and divide each half into five. The primary on the left will be subdivided into 4 secondaries, each of 0·16-inch, representing ¼ mile. (*See* Plate I, Scale 5 (*a*).)

Ex. 4.—*To construct a scale of* 1/20,000 *to show* 100 *metres.*

On this scale, since 100,000 centimetres = 1 kilometre, the length representing a kilometre will be 100,000/20,000 = 5 cms., that is, about 2 inches. Consequently 3 kms. can be shown on about 6 inches of scale. In the absence of a scale of centimetres, we may proceed thus :—

1 metre = 39·370 inches; therefore 3 kms. = 118,110 inches, represented by 118,110/20,000 = 5·91 inches. Divide this length into 3 parts and each third into 2 parts, each of 0·98 inch, representing 500 metres. Subdivide the left primary into 5 secondaries, each of nearly ⅕ inch, representing 100 metres. Compare the map scale on the Service Protractor, Plate XV.

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15. *Construction by Protractor.*—The new pattern ("A" Mark III), of the service protractor is illustrated on Plate XV. It shows a number of scales which can be readily used for the construction of others.

Ex. 5.—*Using the protractor draw a scale of* 4 *inches to* 1 *mile to show* 20 *yards.*

The protractor shows a scale of 2 inches to 1 mile, so that the numbered primaries on the protractor, each representing 200 yards on the 2-inch scale, will represent 100 yards on the 4-inch. Divide the left-hand primary thus obtained into 5 parts, as drawn on Plate I, Scale 1 (*b*).

Ex. 6.—*To draw by means of the protractor a scale of* 1/62,500 *to show* 200 *metres.*

The scale of 1/100,000 on the back of the protractor is utilized in this example. Since 1000 : 625 = 8 : 5, it follows that 8 kilometres on the 1/100,000 will represent 5 kms. on the 1/62,500. Mark off on the drawing twice this length of 8 kms. shown on the protractor, and divide the double length into 10 parts for the primaries of 1 km. each. The left-hand primary, subdivided into 5 equal parts, will then give secondaries of 200 metres interval, as shown on Plate I, Scale 4 (*b*).

The following is a general rule for using the protractor to derive other scales in terms of British units. Regard the 2 inches/1 mile scale as the standard; then:

2,000 n yards on 2ins./1 mile = 4,000 yards on n ins./1m.

Thus suppose the required scale is 1/50,000. This is 1·267 inches to 1 mile; $\therefore n = 1{\cdot}267$. Accordingly, $2{,}000 \times 1{\cdot}267 = 2{,}534$ yards on the 2-inch scale is 4,000 yards on the required scale. If more convenient we can employ 3,000 n on the left side above provided we use 6,000 on the right-hand side of the equation; similarly for other proportions.

16. *Special Cases.*—We distinguish two cases.

Ex. 7.—*To convert to a scale of miles a scale on a foreign map for which no R.F. is given.*

Suppose the map is Russian with a scale of versts. This is a simple example, since the Russian *dyuim* is the exact equivalent of the English inch; the verst contains 42,000 *dyuimam.* Suppose now we discover that 60 versts on the scale is 6 ins., the scale of the map is therefore 10 versts to 1 inch, *i.e.*, 1/420,000.

Again, the verst being nearly $\frac{2}{3}$ of a mile, the 60 versts will be closely equal to 40 miles. Accurately 40 miles on the scale will be $40 \times 63{,}360/420{,}000 = 6{\cdot}03$ inches. Divide this into 4 parts for primaries of 10 miles each, and the left primary into 10 parts, representing single miles. (*See* Plate I, Scales 3 (*a*) and (*b*).)

The number of miles to an inch, $40/6{\cdot}03 = 6{\cdot}63$, should be written above the scale, which is that of the well-known 10-verst map of Russia in Europe.

Ex. 8.—*To construct a scale for a map on which no scale is given.*

If neither the R.F. nor the scale is given and the graticule is not shown, the scale must be found either by comparison with another map on which the scale is marked or by comparing the length between two points on the map with the same distance determined from a ground measurement.

If the parallels of latitude and the meridians are drawn, the scale can be obtained approximately by recalling the fact that the distance between two parallels, one degree apart, is about 69 miles. If the *Text Book of Topographical Surveying* is available the precise distances between the parallels may be sought and the scale determined with accuracy.

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§7. Special Forms of Scale.

17. *Time Scales.*—In military operations distances are occasionally measured by the time required to traverse them, and in this case the linear scale may be usefully supplemented by a scale of hours. Such are scales for marching, running transport, moving forward tanks, cavalry manœuvres, and such like.

Ex. 9.—*To construct a scale of time for a column of troops marching at* 3 *miles an hour.*

Suppose the map in use has a scale of 1/100,000, *i.e.*, 0·6336 in. to 1 mile or 1 inch to 1·578 miles; 6 inches will then be equivalent to about 9½ miles, or something over 3 hours, which will thus be the range of the scale. Now 3 hours = 9 miles is 5·70 inches. Lay off this length on the map or on a small strip of good white cardboard or thick paper, and divide it into 3 parts marked and numbered: Hours 1, 0, 1, 2. Subdivide the left division into 12 parts each of 0·16 inches indicating 5 minute intervals, numbered by the quarter-hours at each third division, as on Plate I, Scale 5 (*b*).

Ex. 10.—*To draw for a sketch on* 2 *inches to* 1 *mile a scale of trotting at* 8 *miles an hour.*

In a quarter of an hour the horse covers 2 miles, equivalent to 4 inches on the scale. Hence divide this length of 4 inches into 3 equal parts, each of 5 minutes, and subdivide the left division into 5 to mark the single minutes, as in Scale 2 (*b*) of Plate I.

It will be found that we might have scaled 4,700 yards off the 2-inch to 1 mile scale on the protractor or cavalry sketching-board and divided the length into 4 equal intervals each of five minutes.

18. *Diagonal Scale.*—This is a device for dividing a primary division into very small secondaries. If carefully drawn it is more precise and more suitable for use than a division attempted with the best form of dividers. Smooth paper and a hard sharp pencil must be used. The scale is constructed as follows (*see* Fig. 1):—

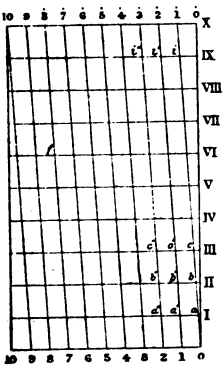

FIG. 1.

Draw 10 equidistant lines, I, II, III . . . parallel to the scale line. In the figure the interval between these lines has been taken at about one-sixth inch, but it may be anything between one-tenth and one-fourth inch; what is important is that the lines should be exactly equidistant.

Draw two lines exactly 1 inch apart perpendicular to these lines. Divide the top and bottom inches into 10 equal parts and number the points of division 0 to 10 as shown.

Join 0 on the bottom line to 1 on the top, 1 on the bottom to 2 on the top; and so on as shown.

Then to measure the distance 0·76 inch, say, run up the diagonal numbered 7 as far as the horizontal line VI. The distance

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from this crossing to the right-hand perpendicular zero line is 0·76 inch.

19. *Gradient Scales.*—A scale of gradient is useful for showing whether a certain slope on a road or hillside is practicable for traffic of a certain class.

Suppose the map has a scale of 1/20,000 and that the V.I. is 5 metres. In Fig. 2 (*a*) is shown a primary of 1,000 m. with

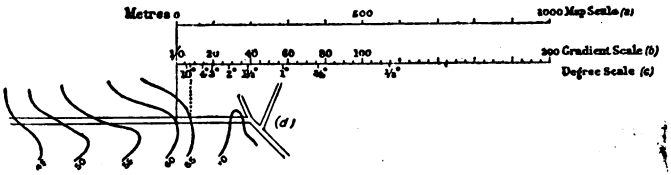

FIG. 2.

its secondaries of 100 m., forming part of the map scale. Now a 5-metre height interval in a length of 1,000 m. implies an average gradient of 1/200; accordingly below the 1,000 mark write 200, as in Fig. 2 (*b*). Similarly divide each number of the map scale by 5, giving the numbers 0, 20, 40 . . .

The zero of this scale represents the slope 1/0, *i.e.*, a perpendicular cliff; the other numbers are the denominators of the fraction which measures the slope in general.

As an example take the road between Dranoutre and Neuve Eglise, Sheet 28 S.W. of the 1/20,000 of France. The contours near the latter village are shown in Fig. 2 (*d*), the steepest slope lying between the contours 60 and 65. Place the gradient scale along the road and bring the zero into coincidence with the 60 contour; the scale then indicates 8 against the 65 contour. On this short stretch (40 metres) of road the average slope is therefore 1/8. The same slope can be read from the degree scale 2 (*c*) as 7°.

Another form of gradient scale is shown on Plate XIX.

20. *Expression of Slope.*—In military terms a slope is usually expressed as a gradient, *i.e.*, as a fraction with 1 as numerator; thus 1/30 represents a rise or fall of 1 foot in 30 feet.

In general, if the V.I. and H.E. are both expressed in the same unit,

$$\text{Mean Slope} = \text{V.I./H.E.},$$

reduced to a fraction with 1 as numerator.

A slope can also be expressed in degrees, so that rules for conversion are required.

An approximate rule for expressing as a gradient a slope given in degrees is to divide the number of degrees by 60. Thus a slope of 3° is a gradient of 1/20. This rule does not hold for steep slopes.

Similarly, if the gradient is known the slope in degrees can be found by dividing 60 by the denominator of the gradient. Thus, a gradient of 1/12 is a slope of 5°.

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In these rules the number 57 gives more exact results than 60; but the latter is more convenient and in any case neither number is correct when the slope exceeds say 20°.

§8. Amount of Map Detail Dependent on Scale.

21. *Comparison of Linear and Areal Dimensions.*—It is important that the student should realize that the area of paper in a map of a given extent of country varies as the square of the scale, when the latter is expressed in terms of a fixed ground unit. Thus a country of given area will cover four times as much paper on a scale of 2 inches/1 mile as on a scale of 1 inch/1 mile. It is therefore in general inadvisable to attempt to crowd upon a 1-inch map all the detail which appears, or would more correctly appear, on a 2-inch map; and conversely, except for special purposes, there is no advantage in merely magnifying detail which is clearly shown on a 1-inch scale, unless further detail is to be subsequently added.

Fig. 3 shows a square mile in its actual dimensions on different scales. The figure exhibits a comparison of scales in a convenient

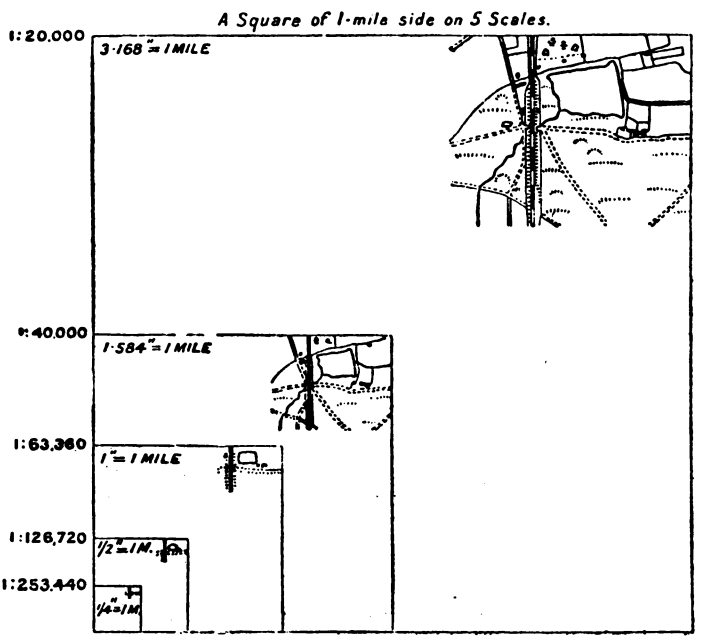

FIG. 3.

form, and, if the detail required to be shown in a square mile is known, gives a good indication of the most suitable scale for the purpose which the map is intended to serve.

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§9. Classification of Scales.

22. It is not possible to draw up a rigid classification of scales; in any such attempt there will result a certain amount of overlapping. Nevertheless for fixing ideas and aiding in the choice of suitable scales, a classification, though unavoidably rough, is desirable. Subject to this understanding, the following may be accepted as a working classification of civil maps at home and abroad :—

1/500 to 1/2,500	...	Town plans.
1/2,500 to 1/20,000	...	Cadastral surveys.
1/20,000 to 1/500,000	...	Topographical maps.
1/500,000 to 1/5*M*	...	Chorographical (maps of countries) and large Atlas maps.
1/5 *M* to 1/50 *M*	...	Maps of continents and general Atlas maps.

§10. Conversion Tables.

23. *The Tables.*—Nautical units are introduced into Table II inasmuch as officers will frequently be called on to read sea or air charts, home or foreign.

The *Geographical mile* is one minute of arc of the Equator.

The *Sea* or *Nautical mile*, on the other hand, is one minute of arc of meridian. It therefore varies in length according to the latitude, as does the *Cable* into which it is divided.

An example of the use of this knowledge is as follows :—

Ex. 11.—*To find the R.F. of an Air Map whose scale is 3 centimetres to one degree of longitude.*

Consider first the charts at the Equator. The table shows that one minute of longitude at the Equator contains 185,537 centimetres, and therefore one degree contains 60 times this number. The R.F. at the Equator is therefore :—

$$3/185{,}537 \times 60 = 1/3{,}710{,}740.$$

But this is not the R.F. at other latitudes. At any latitude λ the length of the minute of longitude is 185,537 cos λ centimetres. Hence the R.F. at latitude λ is $3/185{,}537 \times 60 \cos \lambda$.

At latitude 52°, for example, cos 52° = 0·615 6615.

Thus the R.F. is :—

$$3/185{,}537 \times 60 \times 0{\cdot}615\ 6615 = 1/185{,}537 \times 12{\cdot}31323,$$

i.e., 1 : 2,284,560.

Table IV is given because Russia is the only country of any importance which commonly employs map units other than British or metric.

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TABLE I.—*R.F. and Equivalent British and Metric Scales.*

R.F. 1 to	Miles to 1 inch.	Inches to 1 mile.	Kms. to 1 cm.	Cms. to 1 km.	R.F. 1 to	Miles to 1 inch.	Inches to 1 mile.	Kms. to 1 cm.	Cms. to 1 km.
5 M	78·91	·0127	50	·02	63,360	1	1	·6336	1·578
4 M	63·13	·0158	40	·025	62,500	·9864	1·014	·625	1·6
3 M	47·35	·0211	30	·0333	50,000	·7891	1·267	·5	2
2 M	31·57	·0317	20	·05	42,240	·6667	1·5	·4224	2·367
1½ M	23·67	·0422	15	·0667	40,000	·6313	1·584	·4	2·5
1 M	15·78	·0634	10	·1	31,680	·5	2	·3168	3·157
750,000	11·84	·0845	7·5	·1333	30,000	·4735	2·112	·3	3·333
633,600	10	·1	6·336	·1578	25,344	·4	2·5	·2534	3·946
500,000	7·891	·1267	5	·2	25,000	·3946	2·534	·25	4
400,000	6·313	·1584	4	·25	21,120	·3333	3	·2112	4·735
316,800	5	·2	3·168	·3157	20,000	·3157	3·168	·2	5
300,000	4·735	·2112	3	·3333	15,840	·25	4	·1584	6·313
253,440	4	·25	2·534	·3946	15,000	·2367	4·224	·15	6·667
250,000	3·946	·2534	2·5	·4	12,672	·2	5	·1267	7·891
200,000	3·157	·3168	2	·5	10,560	·1667	6	·1056	9·470
190,080	3	·3333	1·901	·5261	10,000	·1578	6·336	·1	10
150,000	2·367	·4224	1·5	·6667	5,280	·0833	12	·0528	18·94
126,720	2	·5	1·267	·7891	5,000	·0789	12·67	·05	20
125,000	1·973	·5069	1·25	·8	2,500	·0395	25·34	·025	40
100,000	1·578	·6336	1	1	1,760	·0273	36	·0176	56·82
80,000	1·263	·792	0·8	1·25	1,000	·0158	63·36	·01	100
75,000	1·184	·8447	0·75	1·333	500	·0079	126·72	·005	200

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TABLE II.—*British and Metrical Units of Length.*

Geographical Mile.	Knot.	Statute Mile.	Kilometre.	Furlongs.	Chains.	Fathoms.	Metres.	Yards.	Feet.	Links.	Inches.	Centimetres.
1	1·0012	1·1529	1·8554	9·223	92·23	1,014·5	1,855·4	2,029·1	6,087·2	9,223·0	73,046	185,537
—	1	1·1515	1·8532	—	—	1,013·3	1,853·2	$2{,}026\frac{2}{3}$	6,080	—	72,960	185,318
—	—	1	1·6093	8	80	880	1,609·3	1,760	5,280	8,000	63,360	160,934
—	—	—	1	4·97	49·71	546·8	1,000	1,093·6	3,280·8	4,971	39,370	100,000
—	—	—	—	1	10	110	201·2	220	660	1,000	7,920	20,117
—	—	—	—	—	1	11	20·12	22	66	100	792	2,012
—	—	—	—	—	—	1	1·829	2	6	$9\frac{1}{10}$	72	183
							1	1·0936	3·281	$4\frac{971}{1000}$	39·37	100
							—	1	3	$4\frac{6}{10}$	36	91·44
							—	—	1	1·515	12	30·48
							—	—	—	1	7·92	20·12
							—	—	—	—	1	2·54

1 Sea or Nautical Mile.

Latitude.	Statute Miles.	Cables.	Metres.	Feet.
0°	1·1451	10	1842·86	6,046·13
30°	1·1480	10	1847·53	6,061·45
60°	1·1538	10	1856·93	6,092·30
90°	1·1568	10	1861·66	6,107·82
*M	1·1509	10	1852·24	6,076·91

* M is the mean value of a Sea or Nautical Mile. The lengths of this mile as given here are not precisely the same as those adopted by the Admiralty, but the differences are negligible for map purposes.

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TABLE III.—*Metric Square Measures.*

	Square yards.	Acres.
1 Centiare (1 square metre) ...	1·196	—
1 Are (100 square metres)	119·599	0·02471
1 Hectare (10,000 square metres)	11,959·923	2·471058

TABLE IV.—*Russian, Metric and British Units of Length.*

Statute Mile.	Verst.	Kilometre.	Sajenyam.	Metres.	Yards.	Feet. (Futam).	Inches. (Dyuimam).	Centimetres.
1	1·5086	1·6093	754·29	1,609·3	1,760	5,280	63,360	160,934
	1	1·0668	500	1,066·80	1,166·67	3,500	42,000	106,680
		1	468·7	1,000	1,093·6	3,280·8	39,370	100,000
			1	2·1336	2·333	7	84	213·36

Other Russian Measures.

1 Marine Sajen ... ... = 1 fathom.
1 Arshin ... ... = 28 inches.
1 Stopa ... ... = 14 inches.
1 Vershok ... ... = $1\frac{3}{4}$ inches.
1 Paletz ... ... = $\frac{1}{2}$ inch.

The Russian foot and inch are the exact equivalents of the British units.

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Chapter IV.

NUMBERING AND LETTERING AND CONVENTIONAL SIGNS ON TOPOGRAPHICAL MAPS.

§11. Numbering.

24. *Introductory.*—This chapter deals with the signs and symbols used on the printed map, but not with those used for sketching, which will be described in Part II. The interpretation and the understanding of the use of such symbols is a necessary preliminary to intelligent map reading.

25. *Numbering.*—The majority of people are accustomed only to the ordinary atlas map, which usually gives the whole of a country on one sheet drawn to a small scale. When larger scales are demanded, the map of a country may cover many sheets, which have to be arranged and numbered in an orderly series. Each country has its own system of sheet numbering, which should be known to the map user. Indexes giving the entire system of sheets on each scale are always published and give complete information.

The new international air charts are numbered according to a system based on the sheet corner, but the 1/*M* map of the world (*Carte du Monde*) marks the first and most interesting international attempt at standardization of scales, signs and serial numbering of sheets.

The sheets of this series comprise 4 degrees of latitude and 6 degrees of longitude and are numbered systematically according to the following scheme. The 4-degree belts of latitude are lettered A to V from the equator north and south, to latitude 88 degrees; and the 6-degrees zone of longitude eastwards from the anti-meridian, *i.e.*, the meridian 180 degrees east and west of Greenwich. Thus the sheet covering Central Britain, lying between latitudes 52 degrees and 56 degrees and longitudes 0 degree and 6 degrees west, is numbered—

North, N-30.

26. *G.S.G.S. Numbering.*—In extension of this scheme the G.S.G.S. now commonly divides each million-map into 24 parts of 1 square degree each. These "degree sheets" are on the 1/250,000 scale and are lettered from A to X; thus

$$\frac{\text{South, H-35}}{\text{E}}$$

is a degree sheet of the Orange Free State, lying between south latitudes 28 degrees and 29 degrees and east longitudes 28 degrees and 29 degrees.

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These degree sheets are subdivided into four sheets of the 1/125,000; the latter are then ½-degree sheets and are numbered from I to IV. Thus the Abda sheet of the Sinai Peninsula is

North, H-36/K-II,

lying between 30° 30′ and 31° of north latitude and 34° 30′ and 35° of east longitude.

§12. Lettering.

27. Much information is given by the style of lettering; a particular style is applied to features of the same or similar class. Once this is realized, it is immediately known whether a name pertains to a mountain range, a wood, a tribe, or any other description of detail. The different styles of type are not usually included in the references printed on the map, but as the feature to which a name applies is generally obvious, it is easy by comparison to settle any doubtful points.

Plate II has been selected as a typical Conventional Sign Sheet. It gives in generalized form the lettering, colouring and symbols used by the Geographical Section of the General Staff for all their modern topographical maps. It has been substituted for the plate of the ½-inch map of Great Britain, which was in the last edition, because every officer is continually using Ordnance Survey maps and can hardly fail to become acquainted with their characteristic lettering, colouring and symbols.

A brief description of the terms used by cartographers to designate the different types of lettering, with the classes of feature to which they apply, will be found on Plate II.

§13. Conventional Signs.

28. *Design.*—The object of conventional signs is to compress into the smallest possible space the largest amount of information which can be given without overcrowding the map. The signs should be simple in character, so that they may be easily understood, and not too numerous.

Conventional signs vary in different series of maps according to (1) the scale; (2) the nature of the country; (3) the State which prepares the map; (4) the use to which the map is put. The small-scale map will not have the same, nor the same number of, signs as the large-scale map. Maps of an undeveloped country, like Tibet, will require a set of signs differing from those of a European country. Every nation has its own system of conventional signs, varying with the scale.

29. *Characteristics.*—It is not necessary to describe all the signs in use even in the principal European countries and North America. The meaning is intended to be, and generally is, obvious; and if not obvious, it will usually be found in the selection which is commonly printed at the foot of the map.

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Each civilized country publishes sheets of "Characteristics," giving a complete statement of the signs, symbols, abbreviations, lettering and colouring used in the preparation of its maps. The Ordnance Survey publishes separate sheets for the 1/2,500, 6-inch/1 mile, 1 inch/1 mile, and ½ inch/1 mile. It is useful to consult these Characteristic Sheets.

30. *Colouring.*—The colours used on Plate II, viz., black for detail, blue for water and marsh, brown for contours, and green for woods, are those almost universally adopted on modern maps. On many maps, however, *e.g.*, the French 1/80,000 and the Austrian 1/75,000, all the printing is in black. On Bartholomew's maps of the British Isles, colour is employed for water areas, to emphasize roads and to show the shape of the ground by tints or layers; all the rest is in black.

The *water lining* on Plate II is used on none but the best work: on most maps the water is merely tinted blue.

31. *Contour Interval.*—The contour interval is usually mentioned in the map reference, although it can generally be discovered from the face of the map. In the specimen on Plate II the vertical interval is 100 feet; on a 1/250,000 map this interval demands very good drawing and first-class reproduction.

The interval varies with the scale. On the latest English maps the intervals are:—

1-inch map	Interval, 50 feet.
½-inch map	Interval, 100 feet.
¼-inch map	Interval, 200 feet.

Until quite recently the contour interval on the 1-inch O.S. map was 100 feet, but the new Popular Edition of the 1-inch has contours interpolated at 50 feet, which may be taken as the correct interval for this scale.

If we multiply the contour interval by the R.F., the result, known as the "graphic interval," represents the space between map contours on a slope of 45°. Expressed in millimetres, the result is 0·24 for the O.S. maps,—a figure which shows the correct interval for a country with average hill features like Great Britain.

32. *Remarks on Symbols.—Woods* are shown on the Plate in green, but very often the wood is drawn in black and may then have a solid green overprinted. It is preferable to have the woods indicated in green rather than in black; but it is more expensive and becomes impossible when the map is layered.

The symbols for *railways* on Plate II are by no means universal. Often they are shown by a chequer symbol and the cross-bar symbol is quite common.

On O.S. maps *roads* are shown in dotted lines when unfenced, and colour is used to accentuate the more important. This is also a convenient rule in sketching; but if no roads are fenced, it is better to draw them all in firm lines and add an explanatory note.

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STYLES OF TYPE & CONVENTIONAL SIGNS FOR MAPS ON SCALES FROM 1:50,000 TO 1:250,000

Plate II.

	Styles of Type	Name of Type
Countries	LARGE in margin LETTER	Roman, open, shaded, horizontal hatching
Provinces	LARGE do. LETTER	Open stone
Districts	LARGE do. LETTER	Roman Capitals
Capitals of Countries	KHARTUM	do. do.
Large Towns & Capitals of Provinces	WAD MEDANI	do. do.
Small Towns, Govt Stas, Principal Villages	Shendi Shendi Shendi	Roman, lower case
Minor Villages	Intabankulu Intabankulu	Stump
Names of Localities	Wandit Wandit	Egyptian, lower case
Mountain Ranges	RUWENZORI	Egyptian Capitals
Islands & Woods, Plains, Plateaux	Wood, PLAIN Plat.	Roman lower case, sloping / Italic Capitals (fine)
Peaks, Hills	HILL KOPPIE PEAK	Roman lower case, sloping (fine) / Egyptian Capitals
Capes, Passes, Valleys	Cape Pass Valley	Egyptian lower case
Railways, Stations, Bridges, Fords	RAILWAY BRIDGE FORD	Egyptian Caps., sloping
Seas, Rivers, Lakes	RIVER LAKE River	Italic Capitals. Stump
Falls, Wells, Springs	Falls Rapids Wells	Roman lower case, sloping
Marginal Names	QUAGGA	Roman Capitals, hairline
do. do. of Towns & Villages	Shendi 10 m.	Roman lower case, hairline
Notes, Descriptions &c.	Well defined main route	Egyptian lower case, sloping
Tribal Names	KENANA	Roman Caps. uniformly thickened
Heights (Trigonometrical)	1560	Egyptian
do. (Other than Trigonometrical)	1560	do. sloping

Conventional Signs

Anchorage

Boundaries — International; Provincial; Tribal & District

Boundary Pillars — ▲ B.P. 6.

Canals — Lock, Regulator; 1st Class; 2nd do.; Drainage

Churches, Chapels, Mosques — + Church or Chapel without Spire or Tower; do. do. with Spire; do. do. do. Tower; Mosque; Pagoda

Fort

Mission Stations — Protestant + P.M.; Roman Catholic + R.C.M.

Lake

Cultivation — or

Lighthouse, Wireless Station

Conventional Signs (Continued)

Mills

Post Office &c.

Railways — Double; Single; Light; Projected

Rivers — Large Rivers, Falls or Rapids; Perennial, generally running, or in pools; Sometimes dry; Unsurveyed; Nullah, Donga &c.

Ruins

River Passages — Bridges; Ferry; Foot Ford; Wagon Ford

River Dam

Roads in order of importance

Sea Coast

Telegraph or Telephone Lines — Along roads; Along tracks; Not along roads

Trig. Points

Wells &c. — Permanent Wells, Springs; Temporary do.; Wind Pumps; Bucket Pumps; Pipes (Water Supply)

Woods, Heath, Marsh

Steam, Wind, Water

T. Telegraph Office
t. Telephone do.
P. Post Office
When all these exist the following to be used

Tunnel, Culvert, Over Road, Viaduct, Level Crossing, Under Road, Embankment, Cutting, KANA STA.

Falls or Rapids

S. Stone
I. Iron
W. Wood

FERRY, FOOT FORD, WAGON FORD, DAM

Cliffs (or in brown)

Flat Rocks

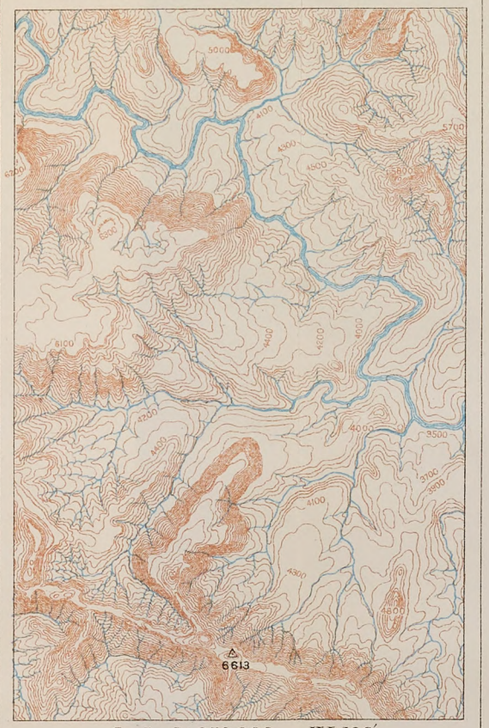
Sand

△ Main Stations ○ Intersected Points

○W. ○S.
×W. ×S.
○W.P.
○B.P.
Pipe

Wood (or in black)
Close, Scattered, Scrub, Heath, Marsh

Contours



Scale 1: 250,000 V.I. 100'

Contours. The contour specimen shown is taken from a map on the 1:250,000 scale. On larger scales, or when the contours are at a greater vertical interval it is better to thicken the contours at intervals of 500 or 1,000 feet according to scale.

NORTH POINT

16° 1907 Ann. Dec. 6'

Magnetic

NOTES

All names and numbers are to be placed horizontally and immediately to the right of the position to which they refer, except where space does not permit.

Names which refer to areas such as Mountain Ranges, Plains, Deserts and Districts must be so spaced as to show the whole area to which they refer. Where however areas cover the whole or parts of one or more adjacent sheets, the lettering will be so placed on the map, that, were the several sheets to be fitted together into one map, the name would appear but once. The letters of this name which would appear on the adjacent sheets will be given in hair-line in the margin.

Railway Station names. In cases where the station name is the same as that of the town in which it stands, STA. only will be written against the station mark. In cases where the station is a considerable distance from the town, the name of the town in Egyptian capitals, followed by STA. will be inserted.

Telegraphs. Unless a note to the contrary is made, it will be understood that a telegraph exists along every railway.

Boundaries. It may sometimes be desirable to accentuate boundaries by means of a colour wash. If the line of a boundary is doubtful the wash should be broken.

Roads. Colour is often used to accentuate the main roads and to indicate their quality. The best roads should have a solid, the next best interrupted, and the third best dotted colour. The colour on the roads would then correspond in appearance with the black used to indicate the three classes of railways.

G.S., G.S. No. 2650 a

War Office 1920

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The design of a *bridge*, whether arched or suspension, is symbolized on many European maps; and the material of the structure, whether stone, iron, wood or concrete, is often indicated.

On European maps much attention is paid to different varieties of permanent *cultivation* and *pasture*, such as vineyards, market gardens, domains, meadows, &c. These maps also often distinguish the different classes of *woods*, such as fir woods, brushwood, &c.

The symbol for *Trig. Point* is practically universal, though in some countries the apex of the triangle is crowned with some decoration to show the nature of the beacon or the order of the point.

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Chapter V.

RELIEF AND ITS REPRESENTATION.

§14. Hill Features and the Methods of Representing them.

33. *Relief Distinguished from Planimetry.*—The construction of a map falls into two separate parts :—

(*a*) Representation of the planimetry or plan detail;

(*b*) Representation of the relief or hill features.

The former process offers comparatively little opportunity for variation; it is the latter which presents the greater difficulty, both to the map maker and map reader.

34. *Methods of Showing Relief.*—There are several methods by which hill features and heights can be shown, and opinions differ as to their relative merits. The methods are :—

(1) Contours,

(2) Form-lines,

(3) Hachures, vertical and horizontal,

(4) Hill shading,

(5) Layer tints,

(6) Spot heights.

Although these methods, save the first two, are distinct in themselves and are often applied singly, two or more may be combined on the same map. Contours and shading are often thus associated, and hachuring is sometimes used along with contouring. Again, in the case of layer tints the hill forms are really shown by contours; the tinting of the various levels between the contours is merely added, thereby facilitating the reading of the map. Remarks on the various combinations employed will be found in Appendix I on British and Foreign maps.

§15. Contouring.

35. *Contours.*—These are best explained by the following simple practical illustrations :—

All students will be familiar with the ordinary wooden or plaster models sometimes used to represent in relief hills and other geographical features.

Say we have such a model, the scale of which we know to be $\frac{1}{12}$, *i.e.*, 1 inch on the model represents 1 foot on the ground.

We place the model in an empty tank or bath, and pour in water until there is 1 inch of water in the bath. The watermark

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will cut the model all round, 1 inch vertically above its base. We draw this watermark on the model with an indelible pencil.

We now add water until there are 2 inches in the bath, whereupon a second watermark is drawn in.

We continue to add water by inches in this way, and to draw in the successive watermarks, until the model is completely covered with water.

On removing the model we find it marked with a succession

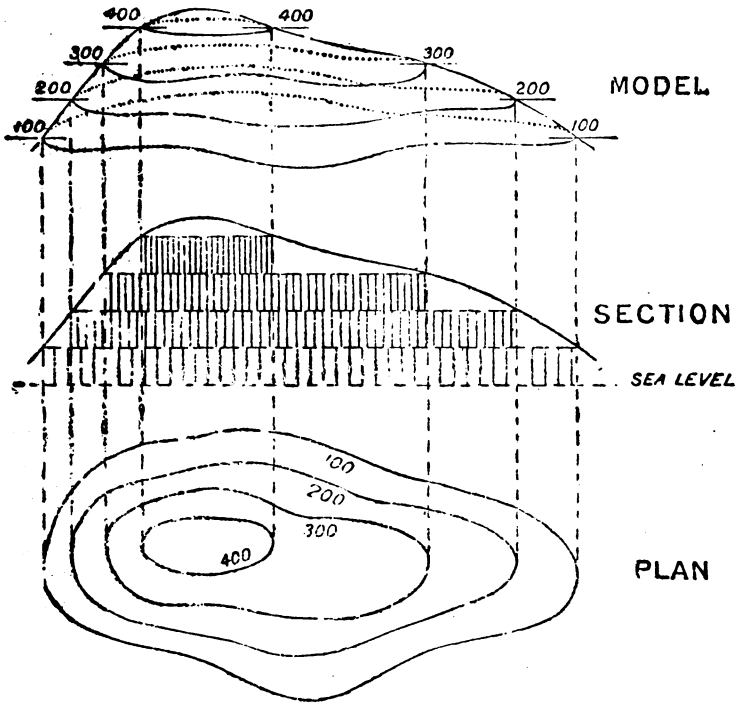

FIG. 4.

View of Hill with Contours supposed to be visibly marked, and Plan of same.

of lines, which we know are vertically 1 inch above the other. These lines are "Contours."

Now, if we make a drawing of the model as seen from above, *i.e.*, a "plan" of the model to the actual scale, we shall have marked on it "Contours" at 1 inch vertical interval—or in other words, we have a map of the actual ground, on the scale of $\frac{1}{12}$, with "Contours" at 1 foot vertical interval.

In practice, for ordinary scales, contours at so close an interval as 1 foot would be too numerous, if not impossible. The interval between the contours depends generally on the scale. Fig. 4 (MODEL) shows the prospect of a hill with contours 100 feet apart; the PLAN below represents the same contours as they would appear on a map.

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36. *Reading Contours.*—The relative position and curvature of contours afford very clear evidence of the shape of the ground. The outstanding conclusions which may be drawn from their forms are here considered; a good map taken on the ground will suggest others. The student should be careful to study the nature of this information, as the person who does not see clearly the evidence of the contours will never become a skilled map reader.

(i) When contours bend they portray a spur or projection; or they portray a valley or re-entrant. To ascertain which, the numbering of successive contours must be examined if there is no distinctive shading in addition to contours.

In Fig. 5, if we read the contours down from 300 feet to 100 feet, and imagine them raised on uprights to scale corresponding to

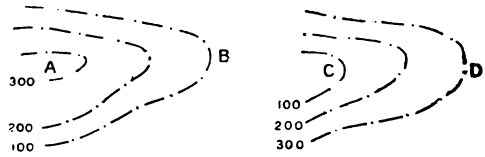

FIG. 5.

these heights, the bend A B is seen at once to be a spur; the bend C D a valley.

(ii) On reference to Plate III slopes are seen to be *uniform*, like A B, *convex*, like C D, or *concave*, like E F.

Now, if contours be drawn in plan to represent a short distance of these slopes, it will be apparent that their spacing in each case is distinctive of the particular kind of slope represented, as follows :—

(*a*) When the contours are evenly spaced as in plan (1) the slope represented is uniform.

(*b*) When the spacing, reading from high to low, decreases, as in plan (2), the slope is convex.

(*c*) When the spacing, reading from high to low, increases, as in plan (3), the slope is concave.

It may be noticed that uniform and concave slopes (1) and (3), viewed from above by an observer at A or E, are visible throughout; in other words, there are no concealed portions to form "dead ground." Convex slopes (2), on the other hand, are a common feature of dead ground.

(iii) If a map shows contours close together, the slope there will be steeper than in places where the contours appear further apart. This will be made clearer by the next Article.

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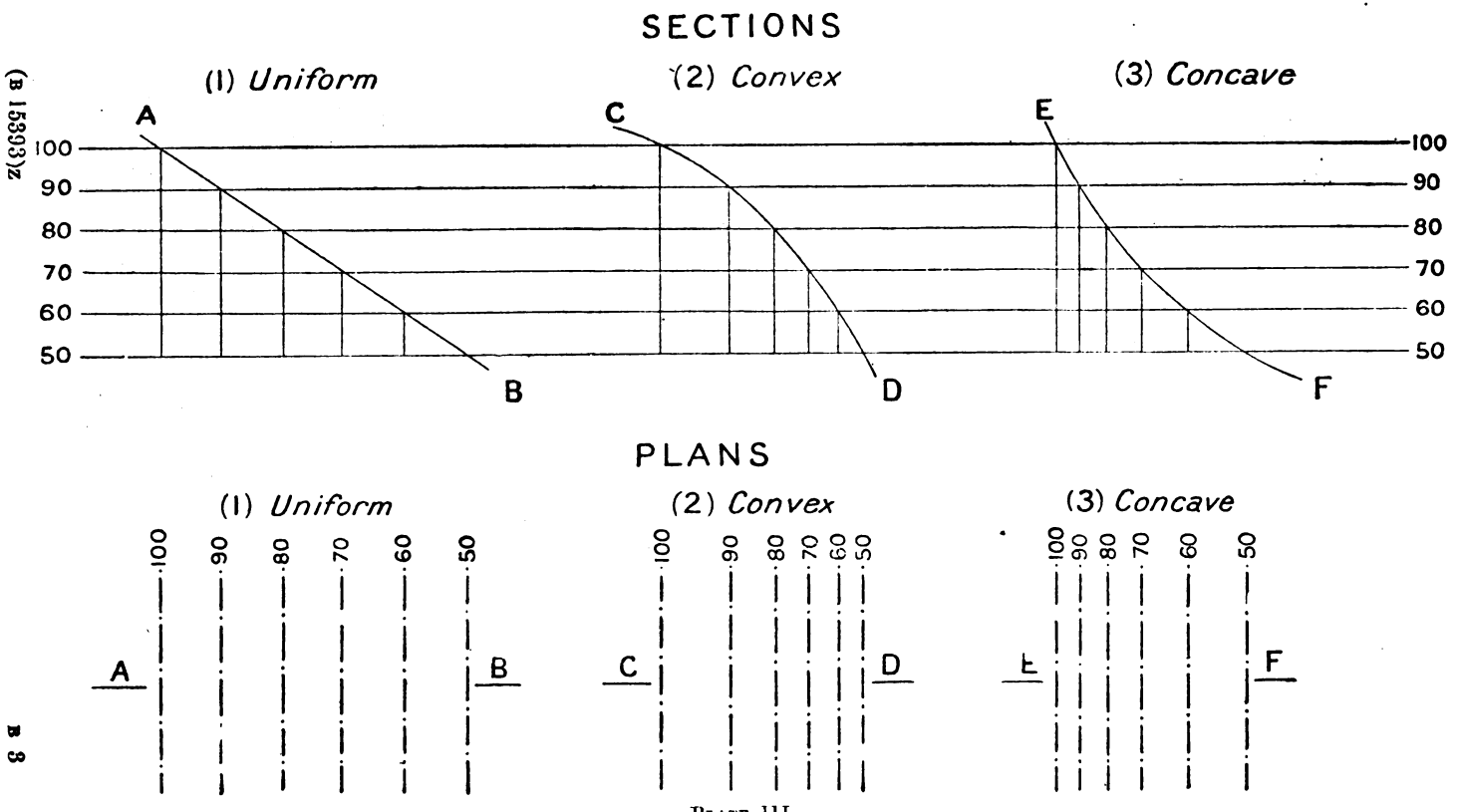

PLATE III.

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37. *Section Drawing.*—In Fig. 6, plan, the ground is steeper at A B than at C D. This is at once apparent if sections be drawn as follows :—

Draw equidistant and parallel dotted lines equal in number to the number of contours which it is desired to show in section,

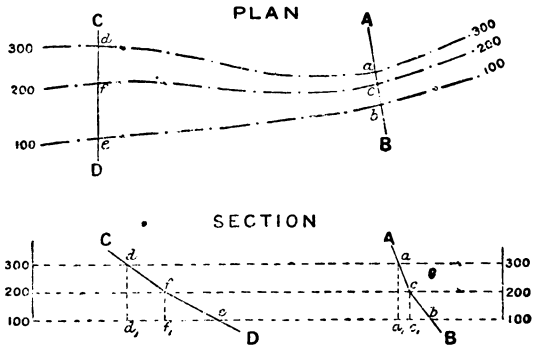

FIG. 6.

in this case three. Number the bottom dotted line to correspond to the lowest contour, in this case 100 ; the remaining lines are numbered 200 and 300 to correspond to the remaining contours. Mark a dot *b* on the lowest dotted line to represent the point where the section line A B cuts the 100 contour in plan. From *b* measure off $b\,c_1 = b\,c$ in the plan. At c_1 draw $c_1 c$ perpendicular to the 100 dotted line, so as to cut the 200 dotted line at *c*. Then measure $b\,a_1 = b\,a$ in the plan, and draw $a_1\,a$ similarly to cut the 300 dotted line at *a*. Draw the line A *a c b* B in the section. The line C D is similarly drawn, and the slopes A B and C D can be compared.

Section drawing of this nature is purely for instructional purposes, and has no practical value. If parallel lines of section, at equal small intervals, are drawn across a contoured map, the interval between the parallels representing, on some exaggerated scale, the contour interval, while distances along the parallels are preserved, a systematic drawing of all cross sections on the same sheet will provide an excellent pictorial means of exhibiting the hill features. As each upper section is completed, the zero of altitude is brought down one line. Such a drawing is known as a " stereogram." The vertical scale may be exaggerated three times in hilly country and more in flat country.

38. *Interpolated and Replaced Contours.*—A contour interval which is adapted to a hilly portion of a country will not be the best for a flat portion. In this case the difficulty may be overcome within certain limits by interpolating further contours. These may be pecked, dotted or chain-dotted or shown by thinner lines to distinguish them from the primary contours.

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In other cases contours which are spaced properly for the representation of moderately hilly country become useless on the face of precipitous slopes or cliffs. In such cases, when the contours would be so close together that it would be impossible to draw or print them satisfactorily, it is usual to show them by a special cliff symbol, as on Plate XXVI.

39. The student should exercise himself in studying the system of contours as a means of depicting hill features. He should imagine some type of ground with various combinations of spur, valley, and slope, and then endeavour to portray these by contours. Conversely, he should draw contours with various curves and spacing, number these successively, and work out the ground they represent. Such preliminary exercises will greatly assist him to read hill features on contoured maps fully, rapidly, and with accuracy.

§16. Other Methods.

40. *Form-lines.*—Form-lines are used when it has not been possible to survey accurate contours in the field. They show the ground in the same manner, but they are not necessarily at regular intervals, and are not reliable for exact information.

In practice it is often very difficult to say whether contour or form-line is the correct designation of a line defining the shape of the ground. At one end of the scale we have the accurate contour which has been instrumentally fixed, such as the 100-feet contours on the "6-inch" map of Great Britain. At the other extreme we have horizontal lines delineating the shape of the ground, but at no regular intervals, as on the 1/250,000 G.S.G.S. map of Eastern Turkey in Asia. Between these two extremes we have every degree of accuracy. The best plan is to regard the lines as contours when they are at regular intervals; but it is seldom safe to assume that the contours have any real claim to precision except in general on the official maps of highly developed and civilized countries.

On sketches, contours are always approximate, being, therefore, strictly form-lines. On small-scale maps, such as the $1/M$, they are much generalized in well-surveyed lands, and usually mere approximations in unsurveyed regions, as in much the greater part of Africa and Asia.

Nevertheless, well-sketched form-lines can give an excellent general idea, on broad lines, of the hill features of a country. The remarks in Art. 36 apply to form-lines as well as to contours.

41. *Hachures.*—These are lines drawn down the directions of steepest slope. For gentle slopes they are fine and far apart, and, as the slope becomes steeper, they are drawn more heavily and more closely together.

They give a good general idea of the shape of the ground, but exhibit no actual measures and afford little positive information.

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Moreover, it is difficult to preserve uniformity of treatment over different sheets of a map. A slope which would be insignificant on a sheet representing a hilly country might be a principal feature in a flat country: in the former case it might possibly not be indicated by hachures at all; in the latter case it must be given some prominence. It is evident that hachures can indicate the existence of a slope, but that they cannot give its degree with any approach to accuracy.

The method was formerly much used, but is not in favour with modern map makers. The French 1/80,000, the German 1/100,000, and the Austrian 1/75,000 are specimens of the hachured map. The English 1-inch map was hachured in its original form.

Hachuring can also be horizontal, but is then of an entirely different nature from hachuring properly so called; the effects of thickening and spacing can, nevertheless, be utilized. The War Office 1/250,000 map of Eastern Turkey in Asia is an example of this style.

42. *Shading.*—There is no difference in principle between hachuring and shading: the same effect is produced in the one case by line work and in the other by depth of tint. In shading the light is usually assumed to be oblique. In combination with contours shading is to be preferred to vertical hachuring. Shading is, therefore, combined with contours on the $\frac{1}{2}$-inch maps of Great Britain and the 1/50,000 of France. On the new 1/100,000 map of Italy shading is effectively combined with contours and a limited amount of horizontal hachuring.

43. *Layers.*—When the ground between contours is coloured by tints which vary according to the level, the map is said to be layered. When differences of level are considerable, a layered map is read more easily than any other, since the relief stands out as on a model (*see* Fig. 4, SECTION). It is the most generally useful method of showing relief, but it fails in exhibiting minor variations of feature, and, unfortunately, owing to the great expense of preparing and printing all the colour plates, it is not possible to prepare all military maps in this manner.

To avoid excessive printing, shades of the same colour are obtained by single-line tinting, cross hatching and solid colour, and the colours themselves are combined in such a way as commonly to give a range from greens at sea level through ochres to browns on the higher mountains, with perhaps whites or bluish-whites on such mountain peaks as rise above the snow-line. Each country has its own range and choice of colour.

44. *Spot Heights.*—Besides the contours or hachures, a good map always gives the height of a number of isolated points, including Trig. Points. On hachured or merely shaded maps these give the only exact information as to level which the maps contain. For showing minor relief between contours, spot heights are particularly valuable.

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§17. Comparison of Methods.

45. *Contours and Form-lines.*—Contouring and good form-lining are the only methods which show up accurately the shape of the ground, which enable slopes to be correctly estimated and which render it possible to solve visibility problems. It must be remembered, however, that, unless the contours are very close together, they do not bring out the minor features. Obviously, if contours are 200 feet apart, there may be hills of less than 200 feet in relative height which are not indicated. It must also be remembered that on small scales contours must be generalized and cannot show all the folds of the ground. Again, it may happen, though rarely, that contours on the surface of a plateau appear to represent prominences, whereas in reality they mark depressions. If the levels are figured and examined, no ambiguity can remain ; but a casual glance may give a wrong impression.

As already stated, there are various degrees of accuracy, from the precisely surveyed contour to the roughly sketched form-line. Instrumentally fixed contours, such as those on the 6-inch map of England, are as accurate as any other part of the map.

46. *Hachures, Shading and Layers.*—The shape of the ground, often even in minor features, can be shown in considerable detail by hachuring, and in a lesser degree by shading, but no exact information is obtainable by these methods.

Layers, as before stated, serve principally to make maps more easily read, and for this purpose are admirable. They do, however, to some degree convey the impression that the ground between the contours is level, as, of course, is seldom the case. This stepped impression is clearly evidenced by Fig. 4 (SECTION). In addition, the adoption of layers necessitates the printing of nearly the whole of the detail in black.

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Chapter VI.

MAP READING.

§18. Outline of Subject.

47. *Proficiency.*—Without maps modern warfare is almost impossible. It follows that the acquirement of the power to to grasp quickly and assuredly the essential features of maps forms an important part of military education.

For proficiency in map reading the knowledge of the expert in map making is not required. Proficiency may be said to comprise, first, an understanding of the various conventions by which natural and artificial features of country are portrayed on maps; secondly, the power to visualize rapidly and accurately the features represented; and, thirdly, the capacity to make full and ready use in the field of all the information which a map is intended to provide.

48. The competent map reader must then be able to—

(*a*) Estimate approximate distances;
(*b*) Interpret the various symbols of cartography:
(*c*) Visualize the nature of the relief, both general and particular;
(*d*) Examine the internal evidence of accuracy or inaccuracy;
(*e*) Determine gradients from a map;
(*f*) Draw visibility diagrams on a map;
(*g*) Read a map on the ground;
(*h*) "Set" a map in the field;
(*i*) Identify his position and march on a map;
(*j*) Understand the nature of graticules and grids.

As a valuable addition to knowledge of maps, some appreciation of the rudimentary properties of a few common forms of projection is required from the fully-informed map reader, but this may be relegated to a more advanced course of instruction.

Of the subject matter outlined above, sections (*a*) to (*f*) are dealt with in the present chapter, (*g*) to (*i*) in Chapter VII., and (*j*) in Chapter VIII.

Besides the ordinary drawing instruments, the student of this chapter is supposed to be acquainted with the Service Protractor and Prismatic Compass. These are described in Chapter XII.

§19. Detailed Examination.

49. *Preliminary inspection.*—After a first general glance the scale of the map should be examined with a view to visualizing distances; for this purpose it may be found desirable to convert a foreign scale into one of miles or yards to an inch.

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The next step is to study the map references, which usually give the interpretation of special symbols, the significance of the colours, frequently the authorities and material on which the map is founded, and sometimes the origins of longitude, altitude and co-ordinates,—all essentials to a thorough understanding. Look out in particular for special notes, which often give the key to the nature of the map.

Relief may not be shown, but a map without relief cannot be considered topographical. When shown, one of the methods described in the previous chapter will be employed. The modern map which makes pretensions to accuracy will be contoured.

50. *Study of Detail.*—The understanding of the detail of the map, as apart from its relief, is comparatively simple. Familiarity with the conventional signs, especially any of unusual form, will make it easy to realize the various details shown and to visualize their appearance ; and hence to appreciate what may be expected on the ground from the representation on the map of such details as a road in a wood and in the open ; to anticipate the appearance of road turnings and the difference between the various types of side roads or tracks ; to visualize what may be expected to be visible of a river or road in a thickly wooded valley ; and so forth. It is necessary to learn to distinguish brushwood from open forest, heath or furze from rough pasture, raised from sunken roads, railways or canals, pits from mounds, fords or level crossings from bridges, drains from fences, and so forth.

51. *Study of Relief.*—The visualization of hill features, or relief, is a more difficult matter. Let us investigate an example of good cartography and for this purpose turn to the portion of map on Plate II, using a magnifying glass if desired.

We see here at first a tract of high-lying greatly broken country, whose main drainage is to the south-east. Differences in elevation exceed 3,000 feet. Extending across the S.W. corner is a lofty main ridge, evidently confining the basin of the main river. The crest of this ridge, which is narrow and has slopes varying from steep to very steep, is in general flattish, with a general altitude of 6,000 feet. Rising from it, however, there are half-a-dozen prominences, in some cases sufficiently marked to be called peaks ; the highest exceeds 6,700 feet. The prominences do not always coincide with deflections in the ridge-line or with the descent of buttresses, as commonly happens in land forms ; nevertheless, from the trig-point 6,613 there descends southwards a marked buttress, and from peak 6,700, the culminating point of the map, there starts, at first north-westwards, a remarkable bent spur ; closer inspections shows further that minor buttresses descend from other prominences. At its western extremity the main ridge turns northwards and rises to 6,500 feet.

The bent spur is the most striking feature on the map. Leaving the chain north-westwards, it turns through a right angle, the deflection taking place at a prominence. The crest, very narrow

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above the bend, considerably broadens below; steep-sided and steep-ended, its extremity would give an excellent command over the valley. Beneath it on the east are some of the few comparatively flat portions of the valley. Note the gully on the west.

Further north on the left of the map is a flat tableland, rising to 6,300 feet, which is evidently another outlier from the chain. Its northern slopes, cut down by the main stream, as is to be expected, are steeper than the southern, which are dissected by the tributary.

Between the tableland and the bent spur lies a coomb, containing a secondary spur (summit 4,900 feet) which descends from the high ridge marking the northward trend of the chain.

The opposite side of the valley appears more irregular. At the extreme north-east corner there is seen to be another watershed, rising to 5,700 feet and probably secondary. A curvilinear spur here descends generally westwards and with two steep-sided buttresses (just appearing at the top) encloses another coomb.

At the top and near the middle there is a flat-topped, steep-sided and steep-ended spur, evidently connecting with the watershed further north, since the streams on either side descend from points above the sheet. Its height is 5,000 feet and the extremity would afford an excellent view both up and down the valley.

Isolated hills appear towards the top of the right-hand margin, where domes rise together to 5,800 feet. Another hill, 4,800 feet, near the south-east corner, is clearly the remnant of an old spur.

The map in general suggests an eroded plateau. The fact that the higher portions are of approximately uniform height, somewhat over 6,000 feet, suggests that we are here nearly in touch with the surface of the original plateau, now much dissected by streams.

52. *Study of English Maps.*—Even in a crowded country such as England, very little explanation is required for the reading of the detail; it is above all a question of knowing the conventional signs and what they represent. It is important, however, to realize how much can be shown on each scale and how much must perforce be omitted, as we have already endeavoured to indicate by Fig. 3.

For this reason Plates IV to VII have been chosen to illustrate the same part of the country, the area of VII being included in VI and that of VI in IV and V. As regards detail, the most obvious difference is that the 1/20,000 map shows fences and enclosures and the other maps do not, except when they are the boundaries of woods, or are in the neighbourhood of towns. This scale exhibits practically all the detail and no imagination is required.

The 1-inch map names many farmhouses and indicates many more without naming them. In more open country it would certainly show, and probably name, them all. On the 1-inch

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scale, however, in country of the nature here portrayed, some houses must be omitted.

On the ½-inch scale the process is carried further, but on the particular specimens here given every effort has been made to show as much detail as possible. A common criticism would be that the map was overcrowded; and so it is, if the main features only are required. Anybody leaving the main roads, however, would probably find the extra detail extremely useful.

Observe the difference of contour interval. On the 1/20,000 the interval is 5 metres, on the 1-inch 50 feet and on the ½-inch 100 feet.

A comparison will show that many minor features appear on the 1/20,000 which are not shown on the 1-inch and on the 1-inch which do not appear on the ½-inch; this is inevitable. Often, however, the smaller scale contains the same information in a generalized form. Take for instance the spur running through squares 2.2, 3.2 and 4.3 on the 1/20,000. This is shown on the 1-inch map by four isolations of the 150-foot contour and two spot heights 144 and 145 feet. These indications show the trained map reader that the shape of the ground must be somewhat as shown on the 1/20,000. Comparisons of this kind on these three maps will provide most useful training.

53. *Maps on the* 1-*in.*, ½-in., 1/20,000, 1/100,000 *and* 1/250,000 *scales.*—Plate VII is a specimen of the new 1/20,000 map of England which has been prepared for training. Plate VI is a sample of the military edition of the 1-inch map and Plate V is the hill-shaded edition of the ½-inch map.

A comparison similar to that suggested in Art. 52 for Plates IV to VII can be made between Plates VIII, IX and XI of the Bailleul-Kemmel region of France and Belgium. Here again we see that none but the largest scale, Plate XI, shows the fences and very many farms and names occur on the 1/20,000 which are not on the 1/100,000 of Belgium and N.E. France.

The 1/250,000 of N.W. Europe, on the other hand, contains nearly all the detail of the 1/100,000; this is rendered possible only by the excellence of the reproduction. The first edition of the 1/250,000 was much more open, but during the war it was found that the map would be more useful if all the roads were added and this was accordingly done.

The contour intervals are as a rule 5 metres on the 1/20,000, 10 metres on the 1/100,000 and 50 metres on the 1/250,000. It is very difficult to read the contours on the last-named map, but the hills of Kemmel, Cassel, etc., are indicated, and it is possible to trace the Messines ridge. These features are quite plain on the 1/100,000 scale. Further east in the hills of the Ardennes the contours show the shape of the ground quite well, but a contour interval of 50 metres is too wide to be effective in flat country even if the contours are not obscured by the large amount of detail reproduced on Plate VIII.

54. *A Sheet of Southern Palestine.*—Plate XII is another map

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on the 1/250,000 scale of a quite different type of country. The contours are at 100 ft. interval and show the ground forms very well. Observe how the hills are indicated partly by firm lines and partly by broken lines. The latter are form-lines, which are occasionally drawn thus, and are not figured. They show the shape of the ground, but give no exact information. Observe also the spot heights, which are very numerous in the contoured area and which, although less numerous, give the only exact information as to heights in the form-lined area. Observe also that all the watercourses are shown by broken lines. This is a common practice when streams are non-perennial.

55. *A Hachured Map and Maps on the 1/M Scale.*—Plate X is a specimen of the French 1/80,000 map. On a hachured map such as this the spot heights have great importance.

Plate XIII is a specimen of the 1/1,000,000 map as approved by the International Conference in London in 1909. The Paris Conference in 1913 made a few changes, the chief of which was to substitute black peck-line* contours for the brown contours on this map. The map is easy to read and requires no explanation. A word of warning is, however, required as to the reliability of the map, and especially of the contours. In Europe it is substantially accurate, but for the greater part of Asia and Africa no accurate surveys are available: the work is a compilation and can never be altogether reliable.

Similar studies of other maps should be made as opportunity offers. Such practice will conduce to proficiency in map reading.

56. *No Map a Perfect Representation.*—Finally, it must be remembered that no map can give a *perfect* representation of country. The expense of close contouring being in general prohibitive, it would be exceptional to get a 6-inch map contoured at vertical intervals of 20 feet, or, as during the war in France to a certain extent, a 1/10,000 map with 5-metre intervals; and even were a map so contoured, minor features of less than 20 feet or 5 metres of relative height would not be revealed.

Such a map could not be used in substitution for a visit to the ground to discover available cover for men, or the precise opportunities for concealment which the ground would afford to an enemy, or the exact course of a good firing line. These remarks apply with particular emphasis to gently undulating or thickly wooded country with slight depressions or sunken features. It will be seen, therefore, that maps are a great aid to, not a complete substitute for, the study of the terrain itself, particularly of its minor features.

§20. Critical Study.

57. *External Evidence.*—The age of a map is often a useful index to its quality, particularly if the reader is acquainted with

* Users of Bartholomew's maps will be familiar with the black peck line contours.

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the history of survey and cartography in the country concerned. It must be remembered that all maps are continually getting out of date, and that an old map cannot show detail of a later date.

Again, the reputation of the map makers, whether official or private, is often a guarantee of good work. This, however, must be qualified by consideration of the material available.

The best evidence as to accuracy or inaccuracy is external to a map. It consists chiefly in the knowledge one may possess of the progress of surveys in the country under consideration, for without good surveys good maps are impossible; moreover, even in surveys, there is a wide variation. For example, some countries, such as the southern part of the Cape of Good Hope, parts of Rhodesia, New South Wales, Queensland, the United States, Mexico and Chile, and New Zealand in general, possess first-class triangulations, and yet are practically unsurveyed topographically. On the other hand, countries in which a considerable amount of local topography has been executed at various times may be practically without a primary framework: parts of Palestine, Somaliland and British East Africa and by far the greater part of Tanganyika Territory, French Equatorial Africa, The Cameroons, Nigeria, Sierra Leone, are some among numerous examples.

58. *Internal Evidence.*—Very useful evidence may be derived from the map itself. We have already spoken of the age, publishers and special notes; attention must be paid to the list of authorities (if given), since, even in the absence of the originals, some evidence may be gleaned therefrom.

The strictly internal evidence is often strong. In general, maps are more lacking in information as to ground forms than as to detail. The representation of the hill features, therefore, should be carefully examined, since it is here that the failings of topographic maps are most likely to show themselves. Hachuring to-day usually denotes great generalization, except in a well-established old series of maps; even layering is often merely a convenient method of generalizing relief. The fact that so-called contours are shown does not necessarily mean that they deserve the name. It must be remembered that contouring is expensive and therefore rare in partially developed countries; form-lining is accordingly more common, and may or may not be combined with a good framework.

59. If the map is patchy one will argue accordingly, unless the patches are oases in deserts. A map showing isolated hills in hachures is immediately suspect. The trained eye will sometimes perceive that rivers are unnaturally straight or curved. The absence of the signs for trig. and intersected points should be noted; as also the absence of spot heights. If the spot heights, though numerous, are all derived from barometric observation, their value is lessened, though not to be despised. It should be remembered also that it is ordinarily more difficult to fix points in valleys than on summits; hence on some maps it will be found

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that both detail and heights in valleys are less reliable than on high ground.

If the map is contoured, it should be seen whether it violates any of the rules given in the last chapter. On contoured maps it is not always impossible to find contours which lose themselves without cause. If a count of the contours is made, starting from a height marked on one side of a valley and ending at a height similarly marked on the other side, a discrepancy may sometimes be found.

60. *Evidence from Land Form.*—The above may be considered the grosser inaccuracies. There are others more subtle in their origin. A pretty map is sometimes founded on very meagre material, and its appearance of accuracy is then so misleading that a smaller scale map with less delineation of feature may be actually more valuable. The precision of detail on the maps of the former German Colonies, for example, is more often due to the skill of the draughtsman than to intrinsic accuracy. It is here that a knowledge of land forms is so often useful, since it leads to the application of certain tests, important not only in critical map reading, but even more so in field sketching.

Thus it is rare that valley-lines (*thalwegs*) are convex, even locally; and if locally convex, there will be intermediate concavities. Hence the first rule: Contours in general become closer as the stream is ascended. Again, it is almost an unfailing rule in a basin that the tributaries fall more rapidly than the main stream. This will be seen from a careful inspection of the contours adjoining the river system of Plate II. The same rule applies to the tributaries of the affluents—the sub-affluents as they are usually named.

61. Then again, notice how in the principal ravine of the same plate the affluents so generally enter the main stream at the bends and from the convex side of the bends. At the confluences of the sub-affluents and affluents the same tendency exists, though not so easily seen on the scale of this map. An exception occurs when two tributaries enter together from opposite sides. Moreover, in flat-bottomed valleys—representing later stages of erosion—the rule no longer holds, since the entering stream is then more likely to undercut the opposite bank. Nevertheless in ravines any general violation of the rule must raise a doubt as to the accuracy of the map.

The reader should examine the map for the fulfilment of another rule, practically universal. The contours nearly always approach nearer to the channel of a river or stream at the downstream side of the bends, since the downward current is at these points deflected by the opposing bank, which in consequence is being continuously worn away. (*See* Appendix III, Art. 346.)

62. In the normal land form, ravines rise to saddles and buttresses to prominences. The buttress or spur normally terminates in a slope, often steep, and commonly at least stiff. As the buttress rises the gradient usually eases until the main ridge is approached, when there is often a short sharp rise to the crest of the ridge.

If these laws, general though they usually be, are constantly broken on a map, one may reasonably doubt the accuracy of the representation of the relief, if not of the plan detail.

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§21. Gradient and Visibility.

63. *Estimation of Gradient.*—The reader of a map must be able to estimate the rate of slope; in other words, the gradient. The method of taking the gradient off a map has been explained in Arts. 19 and 20, so that there is no necessity to repeat the explanation here.

64. *Mutual Visibility.*—In map reading, particularly for military purposes, it is often of the utmost importance to discover from the map whether two points are mutually visible.

Two quick methods of determining whether any point B is visible from any other point A are given below:—

(*a*) *First Method.*—Draw a line joining A and B, Fig. 7. Note any points on that line which are likely to obstruct the line of

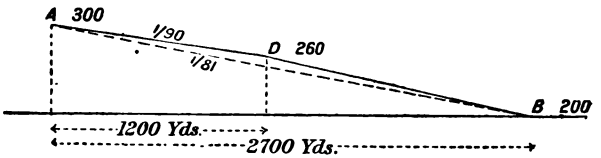

FIG. 7.

sight between A and B, and carefully estimate their position and height.

Suppose there be such a point D whose height is 260 feet, and suppose the height of A is 300 feet and that of B 200 feet. Scale off on the plan the distance AD and also the distance AB; and suppose AD = 1,200 yards, and AB = 2,700 yards.

Slope AD = a drop of 40 feet in 1,200 yards

$$= \frac{40}{1{,}200 \times 3} = \frac{1}{90}.$$

Slope AB = a drop of 100 feet in 2,700 yards

$$= \frac{100}{2{,}700 \times 3} = \frac{1}{81}.$$

That is, the slope AB is steeper than AD; therefore, the point D will obstruct the line of sight AB.

Suppose D has been found to be below the line of sight AB, but that there were several other points, E, F, etc., which might obstruct the line of sight, each could be tested in turn. In this case it might be quicker to proceed by the second method.

65. (*b*) *Second Method.*—Fig. 8(*b*) shows on an enlarged scale the contours on a line on the small portion of map on Plate II.;

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while Fig. 8(*a*) shows a section of the country along this line. It is required to find whether A and B, the two ends of this line, are intervisible.

Now, if the section is drawn as in Fig. 8(*a*), it is immediately apparent that the two points are not mutually visible, since the

FIG. 8(*a*).

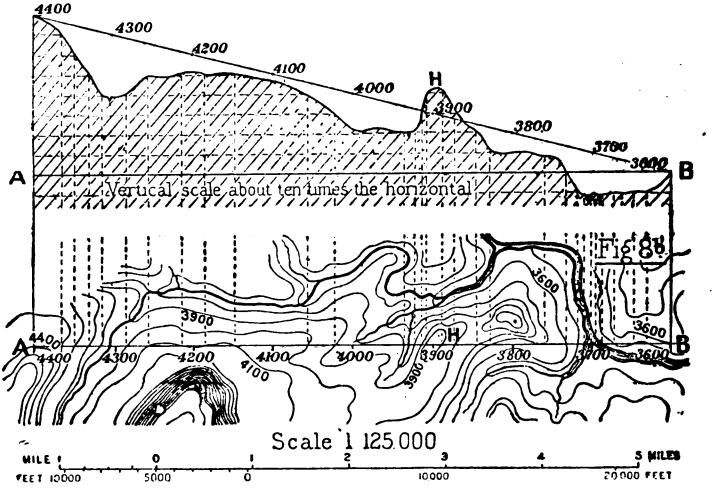

FIG. 8(*b*).

hill H interrupts the line of sight AB. But this method, though otherwise satisfactory, takes time; so that it is desirable to discover a method which does not involve a drawing of the section.

The terminal heights are 4,400 and 3,600 feet, and their difference is 8 vertical intervals. Now, suppose that AB in Fig. 8(*a*) is divided into 8 equal intervals; it is obvious that the divisions marking those intervals, numbered successively 4,400, 4,300, 4,200, . . . 3,700, 3,600, are the altitudes of the line of sight at the points marked. We can, however, equally well indicate *on the map* the several heights of the line of sight; this evidently simply implies that AB, in plan as in Fig. 8(*b*), is to be divided into 8 equal parts. The corresponding divisions thus show the running height of the sight line on the map itself, and it is unnecessary to draw the sectional profile.

It is as evident from Fig. 8(*b*), as from the section in 8(*a*), that the hill H, the height of which is over 4,000 feet, interrupts the line of sight, which at this point has a height of 3,900. Every case will not be so obvious as this, but a careful inspection will always give the desired information.

For the sake of simplicity the heights of A and B have been taken as round numbers. If they are not round numbers, one still divides the difference of height into a number of equal parts

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such that the successive intervals are approximately the contour intervals, and then proceeds to examine the line as before.

66. (*c*) *Graphical Illustration of Second Method.*—In applying the second method, a pair of dividers may not be available in the field, and, further, subdivision is not very easy when the heights of the terminals of the sight line are not round numbers. To avoid the difficulty of subdivision Major C. E. Atkinson has suggested the use of a scale, which within certain limits may be any scale, such as one of those on the Service Protractor; a fully-divided scale is, however, preferable.

In Fig. 9 the sight line is from Mount Rouge (145 metres) to Dranoutre village (60 metres), (*see* Plate XI.). Seek a scale

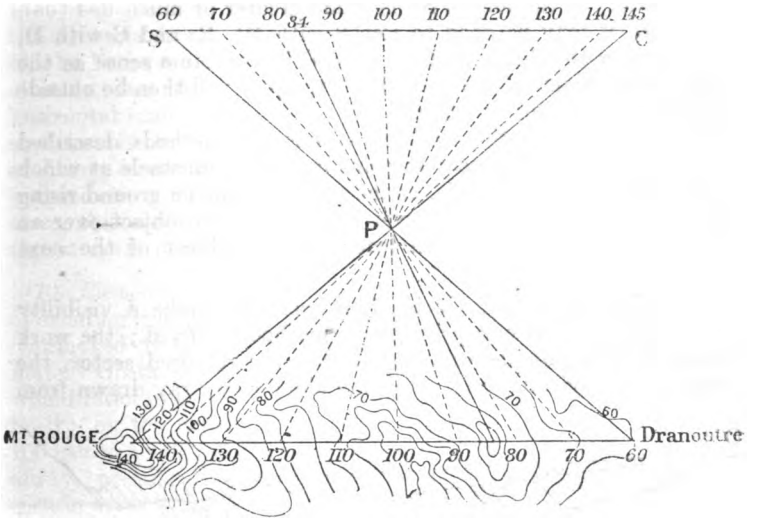

FIG. 9.

such that 85 (*i.e.*, 145 − 60) of its divisions give a length which is comparable with the map length, Mt. R to D. Lay this scale on the map, parallel to the sight line, and draw a line SC along its edge. Tick off the scale divisions on SC and number them as shown from 60 to 145, increasing in the direction of the downward slope of the sight line. Join SD and C Mt.R; these lines cross one another at P—named the pole. Then lines drawn through the pole from the several divisions of the scale will meet the sight line at points which are numbered the same as the corresponding numbers on SC. The sight line is now divided as required by the method.

67. To find whether "Hill 80" interposes an obstacle to the sight ray: The hill has no spot height, but the map appears to indicate that its altitude does not exceed 83 metres. Draw a line from its crown through the pole; this cuts the scale at about

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division 84. Consequently, we find that if the hill is 83 metres, the ray clears it by one metre.

Note that in the illustration we have drawn the full scale along the line Mt. Rouge–Dranoutre, but that in practice this is unnecessary. It is necessary to draw the two lines SD and C Mt.R only in order to obtain P. Then the height of the sight line at any point, such as the apex of Hill 80, for example, is found by drawing a line from this hill through P to meet the selected scale SC.

The line SC should be laid down so that the rays C–Mt.R, S–D cross one another roughly at right angles.

SC may be one, two or more scale-widths from the sight line; this facilitates the drawing of the parallel. It may be placed on either side. If the length SC is much greater or much less than Mt. R–D, it may be good to join S with Mt. R. and C with D, and number the divisions from S to C in the same sense as the required divisions on the sight line; the pole will then lie outside the parallels, below or above.

A little consideration will show that the methods described enable one to find the nearest point beyond an obstacle at which the ground becomes visible, or the nearest point on ground rising backwards at which an observer will see a given object over an obstacle. This investigation leads to the subject of the next Article.

68. *Visibility Maps.*—It is often useful to make a visibility map. There is no new principle or method involved; the work resolves itself into determining, within the required sector, the visible and invisible series of points along every ray drawn from

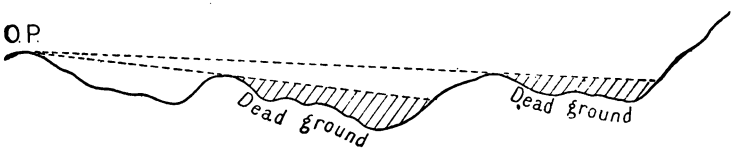

FIG. 10.

the observation post. It is obvious that this implies the consideration of every obstacle along each direction, and the marking out of the "dead ground" rendered thus invisible, as illustrated in Fig. 10.

The method of doing this need not be described in detail. It is simply a matter of fixing the points where a succession of rays from the observation post touch the ground; the lines joining up these points will be the boundaries between the visible and invisible ground. Either of the two methods (*a*) or (*b*), Arts. 64 and 65, or the graphical method of working the latter, Art. 66, may be employed. But the first method would be laborious, while the graphical method would cover the map with a confusing number of lines of no value in the finished diagram; the second method (*b*) is the best of the three.

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69. *Working Diagram.*—It will be found in general best of all to work with the aid of a large sheet of squared paper. We require two scales on this—horizontal and vertical. The horizontal scale of distances is drawn along the bottom of the sheet; on this the squares should represent a round distance of, say, 100 yards or metres. On the vertical scale the side of the squares will represent the contour interval, say, perhaps, 5 metres. The zero of the horizontal scale is to be placed at the height of the observation post on the altitude scale. On the map, centred on the post, draw circles having the same interval as above, 100 yards or metres. In this manner the distance of any point from the post can be read without scaling.

Now, suppose the height of the obstacle is 150 metres, while that of the observation post is 100 metres, and let the distance of the obstacle from the post be 2,000 metres. At 2,000 metres on the horizontal scale run up the squared paper to 150 metres altitude, and mark the point. Join this with the zero of the horizontal scale, whose altitude by rule is 100 metres. The line so drawn is the sight line to the obstacle, and its running height at every distance from the post is read immediately from the squared sheet. It is then necessary simply to compare the heights along this sight line with the heights of objects along the map ray at corresponding distances from the post.

70. *Elements of Doubt.*—It must be remembered that methods of deciding from a map the visibility of a point or of certain areas overlooked by an observation post must be more or less approximate. Obstacles of doubtful elevation, such as woods or houses, would often intervene where the sight ray would clear the ground itself; or the enemy might erect an observation tower, 50 or 100 feet in height, and thus falsify the estimation. It is, however, always possible, provided the contours are accurate, to define certain areas which are certainly dead ground.

71. *Application.*—Visibility maps are of great importance when it is a question of selecting a line of advance which is to be concealed from the enemy's view. They are also valuable in a war of position in determining what ground is or is not visible to the enemy.

72. *Models.*—During the war the French, and later the Americans, made considerable use of models, in plasticene or other material, for the purpose of showing up the dead ground. The shadows, thrown by a small electric light, placed at various points, revealed at a glance the ground invisible from those points. If due precautions are taken to allow for possible error in the construction of the model, this method is valuable, and the model once made, has the great advantage of rapidity in determining the dead ground in front of all possible observation posts, whether our own or those of the enemy.

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Chapter VII.

MAP READING ON THE GROUND.

§22. Map Setting.

73. *Introductory.*—Proficiency in map reading obviously involves the capacity to make full use of a map in the field. The division of the general subject is given in the introduction to the last chaper; we are here concerned with headings (*g*) (*h*) and (*i*) of that outline.

When a map is taken into the field, the reader must first identify his position and then place the sheet in front of him so that the topography depicted thereon may freely unfold itself as the representation of the landscape which is spread out before him. If, for example, he is facing north, the north of the sheet should be held directly away from him. But it may happen that he does not know at once the direction of north. In this case he must find some direction on the map which corresponds with a given direction on the ground. The direction on the ground may be that of magnetic north, given by a compass; or it may be the direction between certain objects in the field which are recognizable in the topography. The process of placing a map in correct orientation is known as *setting the map.*

For the ordinary map user this setting of the map is approximate only, consisting in holding the north of the map towards the north. The student, however, would do well to have a board or some firm backing for his map and learn to set it accurately whilst studying map reading. The processes about to be described really involve the use of such a board.

74. *Setting a Map.*—A map is said to be *set* when it is laid out to correspond with the ground, so that the true north on the map corresponds to the North Point. If, after setting, the directions between features on the ground are then compared with the same directions as shown on the map, they will be seen to be parallel.

(i) *Setting by Compass.*—If the line of magnetic north is shown on the map, produce it if necessary, lay the compass centrally over it and, without disturbing the compass, turn the map slowly round until the north end of the magnetic north line on the map is exactly under the north end of the needle, marked by an arrowhead in the Service prismatic pattern. The map is now set.

If true north only is shown on the map, lay the axis of the compass, *i.e.*, the line of notches in the Service prismatic pattern, directly over this line and turn the map until, against the index at the hinge, the compass card indicates the magnetic variation in the locality. If the variation at a certain place is 15°W., the compass card must read 15° directly; if the variation is 15°E.,

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the card must read 345°. These readings refer to the inner graduation.

(ii) *Setting by Objects.*—A map can be set on the ground without using the north point.

(*a*) When you can identify your position as some point marked or known on the map, proceed to identify also on the map some distant object which you can see. Join this point to your standpoint by a straight line. Then turn the map about your standpoint until this line points to the distant object. The map is again set.

(*b*) When you do not know your exact position, you may find it possible to place yourself in line with some straight feature marked on the map, such as a straight stretch of road, railway, canal, fence or such like. The map is then held so that the directions of this line, as it appears on the map and on the ground, are made one and the same.

Otherwise place yourself in prolongation of a line joining any two objects which can be identified. Revolve the map until the line joining their two positions on the map points towards the two objects in the landscape.

Sometimes it may happen that the only identifiable points nearly in line with you are on either side of your standpoint. In this case you must "line yourself in" (*see* Chapter XIV, §50); this can be done roughly by using the edge of the map as a straight edge, provided you have someone to hold the map steady while you do the sighting.

For setting by resection *see* Chap. XIV, §49, Arts. 164, 169 and 170 and Chap. XV, §58, Art. 213.

75. *The North Line on a Map.*—We have spoken of the north line on a map without explanation. A meridian on a map gives a true north line. In the absence of meridians, which be it noted may be indicated on the sheet margins without being fully drawn, the right and left (or one of the two) sheet edges are sometimes cut along meridians; in any case they ordinarily approximate to true north and south lines. In the topographical maps of the Ordnance Survey, including the new 1/20,000, the sheet edges are grid lines and the vertical grid lines are all parallel to a certain central meridian, which is fixed for maps of a given scale. For sheets through which the meridian passes, the marginal lines are very nearly true north and south; but for sheets in East or West Britain the margins deviate from the true north. The maximum deviation, however, in the extreme eastern or western counties is not more than 4° east or west respectively; that is to say, in the east of England the convergence of meridians causes the sheet line to point east of north, and in the west, west of north.

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§23. Finding Your Position on a Map.

76. It will be observed that in the case considered under ii (*b*) in Art. 74, you do not fix your position, but only a straight line on which your position must lie. With this information, however, the map being set, it is usually quite easy to determine your position with all the accuracy required for map reading as apart from sketching.

In general, in fully developed and fully mapped countries like the United Kingdom, you can fix your standpoint by map detail. The position is first fixed roughly in relation to the greater features around, such as hills, villages, woods, roads and the like.

The locality being thus identified, your exact location is found by means of the smaller features. For this purpose the intersections of fences, the windings of streams, the presence of farmhouses, lanes and tracks, corners of copses and numerous other minor features are utilized according to circumstances. The method of prolongation of straight features as of objects in line with you, though now probably applied to nearer objects, is as useful here as in map setting.

It may happen occasionally that the country is so open or the mapped detail so meagre that you cannot identify your position from detail near by. In this case you must either move to some spot which can be identified or employ some of the methods of resection described in the chapters on sketching by compass or plane table; the compass will usually be the more convenient.

§24. The Map in the Field.

77. *Preliminary Exercises.*—Before proceeding to the field with a map, you should study thoroughly the sheet of the locality to be visited and endeavour to visualize the view as it will appear before you from a given spot. No course of map study can be more instructive than this, for in the field you will have laid out before you the proof of the accuracy or inaccuracy of your conclusions. You should choose some apparently good observation post for your later study on the ground.

When you reach the spot, you will rarely find that you have taken into your mental view all of even the outstanding features. The faults of the indoor study will warn you of the errors of interpretation and visualization to which you are liable and of the danger of issuing instructions in office without the power to form a true mental picture of at least the major features of a country.

You should linger on the errors made and satisfy yourself exactly as to the manner in which any particular feature was overlooked; otherwise the chances are that similar errors will be repeated in future.

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78. *Indoor Sketch.*—The best exercise in map reading is to make in the office a sketch of the view from a chosen observation post as you conceive it will appear. Too much time, however, should not be spent on this sketch; time is an extremely valuable consideration in map reading as in other subjects of warfare. The sketch aids greatly in systematically directing attention, in crystallizing ideas, and in memorizing the various features portrayed on the map. But for the present purpose it should be merely an aid, not an attempt at a finished production.

79. *Alternative Exercise.*—As an alternative when no indoor study has been possible, have a good look at the country first. Estimate distances and heights, remembering the foreshortening effect of perspective. In your mind convert distances into inches on the map scale and sum up mentally what you expect to see on the map. Having gained a definite idea of what the map should look like, turn to it and compare notes. This alternative provides excellent training for sketching.

In the above exercise more will be learnt by systematically working the mind and imagination than by looking frequently from the ground to the map and *vice versa*. Think out the failings of the mental picture. If the country is mapped on different scales, after studying the country on one map it is instructive to examine it on another.

80. *Systematic Comparison of Country and Map.*—In examining a landscape, little of practical value may be gained from the survey, and still less retained in the memory, unless the examination is conducted according to some fixed and definite plan; the result will otherwise be merely a hazy impression, in which the insignificant features, particularly those in the foreground, will often stand out most clearly.

Begin first to examine the characteristic lines of the topography, —the ridge and valley-lines; it is on these that the major features depend. Then follow the brows of the ridges, remembering that the brow is the chief military feature of a hill or ridge or plateau. Next procee l to note the secondary features,— the spurs and buttresses, tributary streams and such like. Any outstanding major or minor feature will thus be usually brought into its proper relation to the whole. Outstanding minor features will include isolated knolls, cliffs, swamps, depressions, woods and the like.

Having thus grasped the leading land forms, turn to the artificial features,—the towns, villages, hamlets, factories, highways, railways, cuttings and embankments, ponds, bridges, telegraph lines and so forth.

As each feature has been studied, turn from the landscape to the map and identify it, noting at the same time the mode of its representation. The map will probably indicate some feature which you have not noticed; refer again to the landscape and mark its relative importance.

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81. *Dead Ground.*—In particular note on the map what you cannot see,—the dead ground. Remember that in modern warfare the invisible is generally more important than the visible. Think of an enemy occupying the ground in front of you. Consider that, knowing you are watching him, he is naturally endeavouring to conceal himself. Determine then the spots where he is likely to be lying. Conversely, consider how best you can conceal yourself from him. Examine his possible view-points and note the ground he is overlooking.

In thus giving rein to the imagination, you will almost unconsciously be making an intimate study of the country in front of you,—a study moreover which is likely to dwell in your mind, especially with a well-read map for reference.

82. *Identification of Objects.*—Sometimes it will happen that an object on the ground cannot be identified on the map. In this case take a compass bearing of the object and draw the line on the map. If a protractor is not at hand, the compass can be used as a substitute. Lay the map flat, in any position, and the axis of the compass over the magnetic north line. Read the bearing and to this reading add the magnetic bearing of the object. Then centring the axis of the compass on your standpoint, turn the instrument till it indicates the line on the map corresponding to the number of degrees thus obtained.

This somewhat laboured method will rarely be necessary. In general even a difficult object will be identified by alignment with others which are recognizable; or by the relative angular distances between it and two other known objects, by adjacent large features; by its height or shape, or in various other ways. Frequently a small change of your position will bring some feature into prominence which will enable the object to be immediately identified.

§25. Marching on a Map.

83. *Marching by Day.*—In finding your way about the country or marching on a map, keep the map constantly set and note each object as it is passed. Maps of scales as small as the ¼-inch are apt to puzzle the beginner in a country so full of detail as England. Much detail is necessarily omitted from such a map, as is evident from Fig. 3.

Thus, in traversing a road, you may find that small by-roads are not indicated, and feel at a loss because you cannot estimate your progress by merely counting the turnings as you meet them. Again, short but decided bends in a road are often not shown; and all curves and bends look more conspicuous on the ground than on maps. On other occasions you may meet with a new road or railway not shown on the map, and in rare circumstances with an old road which has become disused and overgrown. Sometimes it may happen that an old main road has lost its importance and is replaced by another. New construction, particularly of buildings, is often misleading.

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It is a help to check yourself by time as a measure of distances; you may use a time scale. If the map shows the next cross-road 1 mile ($\frac{1}{4}$ inch on map) ahead, it will take, say, 20 minutes to reach it; so that, if you meet with a cross-road in 10 minutes, it is obviously some other than that shown on the map.

Other methods may be utilized. A little closer inspection might show that there is a hamlet, a stream or a wood at the next cross road on the map; if none is visible at the first cross-road, it is again in general safe to assume that the first cross-road is not indicated on the map.

With practice you will learn to glean from the map a great deal of information which it does not appear at first sight to convey. The safe rule is to note everything on the map, even the most minute detail, within a reasonable distance off the route you are traversing, including the detail a little way ahead of your position.

You are prone to neglect the contours, which, by indicating a rise or fall of level, would enable you in many cases to assign your position on the map. Further, points fixed beyond question in the rear aid greatly in resolving doubts in subsequent advance.

84. *Marching by Night* on a map is naturally more difficult than by day, since many distinctive features are then invisible. The watch and compass are then of more than ordinary assistance. If you are to traverse a selected route, you will find it advantageous to make a very rough sketch or tracing of the route, on which are marked the general bearings of the various sections of the route, the time at which you should arrive at the various stages of the march, the turnings you should take, and the conspicuous objects you should see at night.

Further information on night marching is given in Chap. XXI.

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Chapter VIII.

SQUARED AND GRIDDED MAPS.

§26. Squared Maps.

85. *Squaring for Reference.*—In the late war the need for some system of reference by which the position of a place or of a definite point, such as a gun position, could be rapidly and accurately identified, became apparent. Maps which have a reference system may be divided into two classes :—

(*a*) Squared maps ;
(*b*) Gridded maps.

By squared maps we mean those in which each sheet, regarded as an individual map, is by some means divided into sections, which are identified either by marginal letters and numbers or by letters or numbers printed on the face of the map. Each sheet may be divided into sections either by the graticule, *i.e.*, the lines of latitude and longitude—in which case the sections are not truly squared—or by a system of squares specially drawn and bearing no relation to the graticule. In the latter case the squares, though drawn according to the same scheme on the various sheets of a series, are often wanting in common boundaries at the margins of adjoining sheets.

The sheets of the G.S.G.S. 1/100,000 map of France and Belgium are divided into sections by the graticule. The 1/20,000 and 1/40,000 sheets of France and Belgium had a system of squares overprinted on each sheet. The sheets of the 1/250,000 map of Flanders are divided into squares by lines drawn across them at intervals of 2 inches.

On these maps it is necessary to give as reference first the sheet number and then the letters and numbers identifying the square. This locates a town or village within the square with sufficient accuracy to enable it to be found immediately.

This method of providing a reference by dividing each sheet of a map into sections is usually sufficient for small-scale maps, but it is not enough for regulating artillery fire, nor for other purposes of modern warfare. It is then necessary to be able to calculate the distance and bearing between two points, whether they are on the same sheet or on different sheets, and this can be done correctly and with ease on gridded maps alone.

Troops must, however, be prepared to use any form of squared map.

§27. Gridded Maps.

86. *Gridding for Survey and Reference.*—Good maps, as apart from mere sketches, must in general be based on a system of triangulation, by which points can be fixed with great accuracy. The positions of these points can be calculated and plotted by

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means of their *Geographical Co-ordinates, i.e.*, by their latitude and longitude, or by *Rectangular Co-ordinates, i.e.*, by their distances east (or west) and north (or south) of a selected origin. Geographical Co-ordinates can be converted to Rectangular Co-ordinates, and *vice versa*. In any theatre of military operations in which large-scale maps are to be used for controlling artillery fire it is necessary to provide a system of triangulation, if it does not already exist, and to express the position of the fixed points by rectangular co-ordinates.

If we now select an origin and draw a line through it running due north and south and another through the origin at right angles to the former, and if we further cover the *whole* map, consisting perhaps of many sheets, with lines drawn parallel to these "axes" at intervals of 1,000 metres or 1,000 yards, we shall have the whole map divided into squares of 1,000 metres or yards; the distances of the corners of these squares east and north of the origin will then be known precisely.

To locate a point it will then be necessary merely to measure its distances east and north of the S.W. corner of one of these squares (of 1 kilometre or 1,000 yards side, as the case may be), and add the co-ordinates so found respectively to the east and north co-ordinates of the S.W. corner of the square, which we may now describe as the kilometre square.

87. *Advantages of a Grid.*—This system has several advantages over maps which are merely squared.

(*a*) The system of co-ordinates used by the Army surveyors is the same as that used by the Army in general. In the late war the British Army used maps squared according to an arbitrary and independent system, while the surveyors for their own work had to employ rectangular co-ordinates. When, therefore, the survey gave the Army the position of a point, they had to plot it by rectangular co-ordinates and then measure off the reference as used by the Army. The reverse process was necessary when the position of a point was received from the Army. This entailed much waste of time and labour.

(*b*) The system is independent of sheets and of the scale of the map. If the regular sheet system could always be used, this would not be so important; but special sheets are often necessary, and it is a great gain to be able to define a point without naming a sheet.

(*c*) It is possible to calculate very simply the distance between two points and their relative bearing, whether the two points are on the same sheet or not. This is a point of great importance for the artillery.

Gridded maps were used by the French throughout the war. Our large-scale maps had sheet edges which were grid lines, but the sheet itself was, properly speaking, squared only. This system, though at first unavoidable, enormously enhanced the difficulty of taking distances and bearings from the maps. To

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avoid this and other difficulties, we were about to adopt the grid system when the Armistice intervened. In any future war involving the use of large-scale maps, the grid system will certainly be used.

A scheme for covering Great Britain with a system of gridded 1/20,000 maps has been prepared, and the sheets covering the various military centres are in course of publication (*see* Plate VII.). The system adopted is the same as that finally approved for use in France, and its importance justifies a detailed description.

§28. The New Grid.

88. *The Allied System.*—In the following description of the system of map reference adopted by the Allies, and now adopted in Great Britain, metric units of measurement are used throughout because these were actually used, and the decimal division is necessary. But it should be understood that it is not in any way essential that kilometre squares should be used in this system; 1,000-yard squares would do just as well, and if co-ordinates are measured in yards the squares must be in yards. The point of the system is that, whatever units—metres, yard or feet—are used for the rectangular co-ordinates, the dimensions of the grid squares (for map reference) must be some multiple of 10 of the same unit. Actually 1,000 is the most convenient size.

89. (*a*) *Grid.*—The area of operations is covered with a continuous network of lines forming squares of 1 kilometre (1,000 metres) side. This network is called the "grid." The fundamental straight lines or "axes" (§4), Grid North and Grid East, are drawn north and east through the origin of the rectangular co-ordinates, and the other lines of the system are drawn parallel to them; each of the mapped grid lines is a certain number of kilometres east or north of that origin.

90. (*b*) *Designation.*—Starting from the origin, every tenth grid line is emphasized. These tenth lines form squares of 10-kilometre side, and each of these is given a letter. In a square of 50-kilometre side there are twenty-five 10-kilometre squares, denoted by 25 letters, A to Z, omitting I.

Each kilometre square is given a 2-figure number, which represents the co-ordinates of its S.W. corner in kilometres measured from the S.W. corner of the large lettered square.

Thus squares are known as follows:—

Large (10-km.) squares by a letter ...A.
Small (1-km.) squares by a number ...25.

These letters and numbers are printed on the map. Along the margin of the map are printed also numbers which represent the distance in kilometres of each grid line east or north of the origin. Every tenth line has this number in full, while the intervening lines are numbered 1 to 9. *See* Figs. 11 and 12 and Plate VII.

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System of Numbering
1 Kilometre Squares.

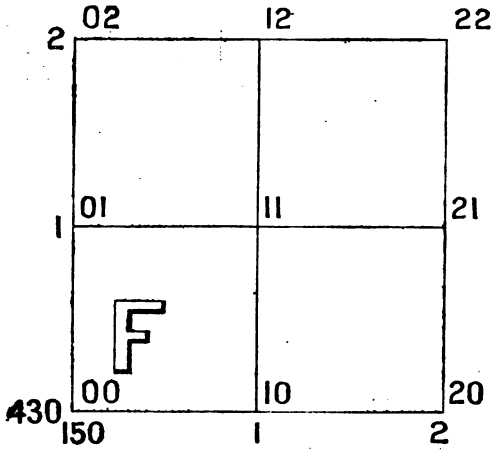

Fig. 11.

System of Lettering
10 Kilometre Squares.

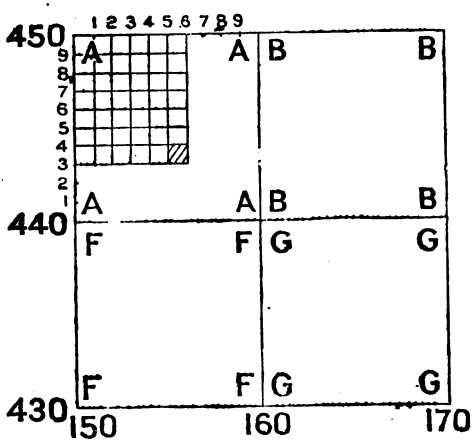

Fig. 12.

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91. (*c*) *Description of a Point.*—The position of a point is described by its co-ordinate *in the large lettered square.*

Consider square 5, 3 in Fig. 12; this is shown in full size in Fig. 13. Suppose that the co-ordinates of a point P in this square are 4, 6, measured in the usual way by taking so many tenths of the side east and north. Since a tenth of a kilometre side is 100 metres, this means that P is 400 metres east and 600 metres north of the south-west corner of square 5, 3. Now the number 53 means that the south-west corner of this square is 5 kilometres east and 3 kilometres north of the south-west corner of the big square. Therefore the co-ordinates of P in the big square are (in metres) 5,400 east and 3,600 north; and the map reference of point P is A. 5,4–3,6.

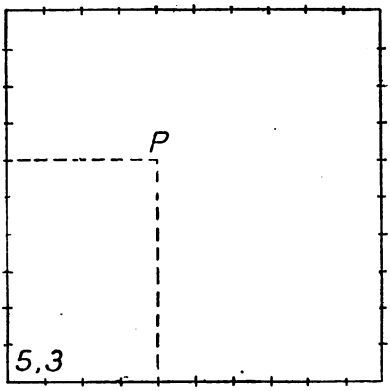

FIG. 13.

If we want to describe P more accurately we take hundredths of the square side instead of tenths, and use 6-figure co-ordinates. Thus, supposing P to be 410 metres east and 620 metres north, its "pinpoint" co-ordinates are A. 5,41–3,62.

Four figure co-ordinates describe a point to the nearest 100 metres and six figure to the nearest 10 metres.

Observe that there is no numerical connection between the two figures in the kilometre square. The first figure is always the co-ordinate of the kilometre square measured east from the S.W. corner of the large (10-kilometre) square and the second figure is the co-ordinate measured north.

92. (*d*) *Use of Square Letters.*—The letter denoting a 10-kilometre square is adopted as a convenient abbreviation to show the position of the square and to save writing the full co-ordinates. Thus Fig. 12 shows that the square A lies between 150 and 160 kms. E., and 440 and 450 kms. N. of the false origin. Further it means (and this is important for conversions) that every point in square A has full co-ordinates which begin with 15 and 44.

Square letters are repeated at every 50 kilometres. Thus, the next square A lying to the north is situated between co-ordinates 490 and 500 north (with the same easterly co-ordinates) and all points lying within this square have full co-ordinates beginning with 15 and 49.

It may often be the case that there can be no doubt as to the 10-kilometre square in which a point lies. If, for instance, a

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sound-ranging section were observing or ranging a battery, the position of the points given as the location would not ordinarily be doubtful to the extent of 10 kilometres. In such cases it would not be necessary to give the letter of the 10-kilometre square; the abbreviated co-ordinates, that is to say, the co-ordinates without the addition of the letter, would be sufficient. The French used the system throughout the war without these letters; but it is impossible to say if mistakes occurred. The letters form an additional safeguard and are a convenience.

If there is any risk of a square being mistaken for another, 10 kilometres away, the correct letter must precede the reference.

Square numbers within a 10-kilometre square are all different and no confusion can arise between them.

93 (*e*) *Map References.*—The map reference of a *point* must always be given by not less than four figures. Thus, while a square is known as 47, the *point* at the S.W. corner of the square is 4,0—7,0.

In reports a stop or comma should always be put after the figure denoting *kilometres*, and a line or dash between the east and north co-ordinates; so that references would be written in any of the following forms :—

5,4–3,6; 4·57–6·83; 3·21/5·42.

This arrangement is logical, as the co-ordinates are actually kilometric co-ordinates; that is to say, co-ordinates expressed in kilometres and decimals of a kilometre.

94. *System based on Survey Co-ordinates.*—The above description shows how *map references* are given. When exact co-ordinates are required for calculations, the full figures must be given. Thus for the same point P the co-ordinates to the nearest metre might be :

155·412 East; 443·623 North.

It will be seen that this system of map reference is based directly on the survey co-ordinates of the point in question. The same figures (with certain exceptions mentioned below) appear throughout, and the map reference is obtained by omitting figures that are unnecessary.

This can be seen by the following example, which shows the way in which figures are gradually dropped as the description becomes less and less precise :—

	East.	North.
RECT. CO-ORDINATES	155,412	443·623
MAP REFERENCE—		
6-figure	A 5,41	3,62.
4-figure	A 5,4	3,6.
KM. SQUARE	A 5,	3,

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In certain cases the same figures do not appear throughout. For example, if a co-ordinate is 449,999, the *nearest* figure to this for the abbreviation is 450,000. Cases will occur also where the square quoted in the 6-figure reference is different from that in the 4-figure.

Examples of changes in figures and letters are given below :—

Rect. Co-ordinates.		Map Reference.	
		6-figure.	4-figure.
164,379	438,228	G 4,38–8,23	G 4.4–8.2.
167,988	442,991	B 8,00–2,99	B 8,0–3,0.
169,990	441,002	B 9,99–1,00	C 0,0–1,0.
159,998	439,982	G 0,00–9,98	B 0,0–0,0.

Note the third and fourth examples. In the third the point lies so near to the eastern edge of square B that the 4-figure reference (which gives the position to the nearest 100 m.) must be given in the adjoining square C.

Similarly, in the fourth case, the point lies in the extreme north-east of square F. The 6-figure reference must be given as if it lay on the western edge of square G ; and the 4-figure as if it were the extreme S.W. point of square B.

Note that the designation of the *square* in which the point lies is not affected. The above four points lie in squares G 48, B 72, B 91 and F 99.

It should be noted that the Map Reference, though it gives an approximate position only, defines an actual *point*, and not an area. This point lies within 100 metres or 10 metres of the true position according as a 4-figure or 6-figure reference is used. On the other hand, when the kilometre square is given (as A, 5.3), it is the *area* which is defined.

The above examples are given for illustration only. In practice no difficulty need be apprehended, as the usual procedure, in referencing, is not to start from the trig. co-ordinates, but to take the point as it appears on the map and describe it by the nearest map reference.

95. *Bearings on a Grid.*—On a gridded map all bearings are to be given with reference to grid north and not to true north.

It is important that all officers should habituate themselves to define the positions of points on squared and gridded maps by the decimal system and to apply the new system of referencing. Plate VII can be used for this purpose.

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Chapter IX.

MAPS OF THE BRITISH EMPIRE AND FOREIGN COUNTRIES.

§29. General Sketch.

96. *Maps of Europe.*—Plates IV to XIII contain specimens of some of the maps of Great Britain and France, and some of the maps prepared by the General Staff.

A list of the principal topographical maps of the world is printed in Appendix I. It will be seen that the area for which such maps are available is confined principally to Europe; the labour of preparing such maps is so great that even the United States have as yet covered, with accurate topography, about two-fifths only of their vast territory.

97. *Maps of Asia.*—In Asia regular mapping has been hitherto almost confined to the Survey of India and to a smaller extent Japan. In isolated areas, however, a certain amount of topography has been completed; as for example in the Federated Malay States, Siam, Java, Indo-China, Hong Kong, Wei Hei Wei, Vladivostok, &c. In Palestine, a considerable proportion of the whole was surveyed and mapped by the Committee of the Palestine Exploration Fund. During the war the Turks made a large contribution to the mapping of Eastern Asia Minor, while our Armies revised and extended the topography of Syria and Palestine, and added much to the geographical knowledge of Mesopotamia. In general in Asia, however, war would have to be waged on a small-scale compiled map of very doubtful quality.

98. *Maps of Africa.*—Egypt is well mapped and the Anglo-Egyptian Sudan is covered by 1/250,000 sheets of varying degrees of accuracy, including much good survey. Uganda and British East Africa have 1/250,000 maps, almost complete for Uganda, and there are some sheets of a 1/125,000 series in the neighbourhood of Nairobi. The Germans produced five excellent sheets of Usambara and Massoko, but their 1/300,000 series of former German East Africa is a compilation for the most part, based on itineraries and sketches. The same remarks apply to the similar maps of the German Cameroons and Togoland.

There are no topographical maps of the Belgian Congo, nor of the Portuguese possessions in Africa, unless along some of the international frontiers, chiefly British. The French have produced excellent maps of Algeria and Tunisia and are now engaged on Morocco. The Spaniards have prepared one map of the Tangier and Ceuta region and about 5 sheets in the neighbourhood of Melilla. Italy has a good plane-table series in a central part of Eritrea.

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In South Africa there are excellent topographical maps of the Orange Free State, of Basutoland, Northern Natal and a small portion of the Southern Transvaal; and a reconnaissance survey on the 1/250,000 scale of the northern portion of Cape Colony. The Geological Survey of the Union is issuing geological maps with a limited amount of topographical information. In the remainder of South Africa, except at Cape Town, there are no topographical maps.

In West Africa some sheets have been surveyed in the Gold Coast and there are full topographical maps on the 1/125,000 scale of the south-western corner of Nigeria. In Sierra Leone the Freetown peninsula has been surveyed.

99. *Maps of America.*—Canada possesses a 1-inch series in the more valuable portions of Ontario and Quebec, and relatively small areas have been surveyed on the frontiers of Washington State and Alaska. There is also a photographic survey of the Yukon by Captain Deville. In addition the Department of the Interior has published provisional maps on the scale of 1/250,000 or 1/500,000, covering Eastern Canada from the Lake of the Woods to Nova Scotia; but these are wanting in relief. Of greater topographical value are the sectional maps of Alberta, Manitoba and Saskatchewan on the scale of 1 inch/3 miles, with contours of varying intervals. The Geological Survey of Canada has also prepared some topographical sheets and the Geodetic Survey is now proposing organized mapping.

The Geological Survey of the United States is continuously engaged on topographic maps, the areas already completed consisting chiefly of the Eastern States, Kansas, Missouri and Texas in the south centre and California and Washington on the Pacific Coast.

There are no topographical maps in South America except of a few small localities in the Argentine, Brazil, Chile and Uruguay.

100. *Cadastral Maps* are not in general of military value, except in so far as, being constructed on a usually very accurate framework of triangulation or main traverses, they form an excellent basis for topography. The cadastrals in France were invaluable for this purpose during the war.

101. *List.*—The maps enumerated in Appendix 1 are based on surveys which give substantial accuracy on the scale of reproduction, unless in those cases where the notes state that the map is compiled or where hachures or form-lines in a country not fully developed are obvious indications of imperfect or partial surveys.

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CHAPTER X.

SPECIAL MILITARY MAPS.

§30. Classification of Military Maps.

102. *Introductory.*—Military maps are frequently grouped in broad classes under the headings *small-scale, large-scale, strategical, tactical,* and so forth. It should be understood that there is no hard and fast line between such classes ; but, as the terms are so commonly used, and since they convey certain definite ideas to the speaker but not always to the hearer, it is desirable to explain their meaning.

Military maps may be classed according to scale most conveniently and correctly as *strategical, small-scale* and *large-scale* maps.

103. *Strategical maps* are used for the consideration of the field of operations as a whole. They are usually of quite small scale, such as 1/*M*, 2/*M*, &c. Scale is not the only consideration : the requirement is really a map showing the broad features of topography without unnecessary details. Maps on the 1/250,000 or 1/100,000 scale have been used for strategical purposes, either in skeleton form or with the principal names and features emphasized ; but generally speaking a map of larger scale than about 1/300,000 becomes too unwieldy for strategic use.

104. *Small-scale maps* are required for marching, manœuvring, administrative and other purposes. Their scale may be said to range from about 1/250,000 to about 1/60,000 ; or say from a quarter to one inch to the mile. British $\frac{1}{4}$-inch, $\frac{1}{2}$-inch and 1-inch and Continental 1/100,000 are the best known examples of this class.

105. *Large-scale maps* are required for modern warfare in European conditions. It is generally agreed that for modern fighting—as opposed to manœuvring—with fully equipped forces, the smallest scale that is practicable is the 1/50,000 ($1\frac{1}{4}$ inches to 1 mile). Large-scale maps may therefore be regarded as of this scale and upwards.

106. *Tactical Maps.*—The proper definition of a tactical map is a map which shows enough detail to enable a commander to study tactical problems and to work out a tactical plan. In this sense no map of smaller scale than $\frac{1}{2}$-inch to the mile, or 1/125,000, can be considered a tactical map. Maps of smaller scale, *e.g.*, 1/250,000, have often been placed in this category, but the truth is that when such are the only maps available tactics are evolved on the ground without any aid from the map, which is of use only for getting about and indicating main communications.

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With the proviso that nothing smaller than the ½-inch can be seriously considered for tactical purposes, it may be stated that it is impossible to lay down exactly what is or is not a tactical map. The ½-inch may serve the purpose in certain circumstances; but experience has shown that in various conditions the 1/10,000 1/5,000 or even 1/1,000 scales may be necessary: it depends entirely on the circumstances and the nature of the operations.

From what has been said about the 1/50,000 it will be seen that this scale is considered the smallest practicable for tactical purposes in modern European warfare.

§31. Summary of Military Maps.

107. Strictly speaking, there is no such thing as the purely military map. All countries use the ordinary topographical maps of the country, which are equally useful to the soldier or to the civilian, though they were for the most part prepared in the first instance for military purposes. In war, however, military information of all kinds can be added either to the complete topographical map or to a bare outline from which the hill features are omitted. Such maps are required for many purposes and in France towards the end of the war their number was considerable. We give below a list of such maps, all of which had special military information printed on the base map.

108.—(i) *Situation Maps*, showing disposition of the enemy's forces. These maps in France were generally known as the *Enemy Order of Battle.*

The maps varied in scale from a 1/million skeleton map, when it was desired to cover a large area, to the 1/100,000 or even larger scales when the object was to show the hostile troops facing an army or a corps. In every case the outline was printed in grey and the necessary information overprinted in colours.

Small-scale situation maps were printed weekly for every theatre of war; the larger scales were printed by armies as required. Small-scale skeleton maps for this purpose are essential in every campaign.

(ii) *Enemy Organization Maps* were printed to give all available information as to the enemy's fighting and administrative organization.

(iii) *Trench Maps* on the 1/10,000 and 1/20,000 scales. These were the ordinary large-scale maps with the enemy's trenches overprinted. In the later stages of the war in France our own trenches were also shown, but previously they had been confined to secret editions.

Experience showed that the advantage to our own troops of having a good map of our own trenches outweighed the value of any information that the enemy might obtain from captured maps. Secret trench maps were then confined solely to those which gave information such as could not be obtained from air

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photographs; as, for example, positions of ammunition stores and other details of organization.

(iv) *Special Railway Maps* were usually on the 1/100,000 scale. The base map was printed in grey and the railways in colour. Decauville lines were included. By reason of the unceasing activity it was impossible to keep the editions of the ordinary map up to date and it was most useful to have special editions in which the railways were the prominent feature.

(v) ***Road and Bridge Maps.***—These maps do for roads what the railway maps do for railways and are prepared in the same style.

(vi) *Traffic Maps* show how traffic should circulate in any given area.

(vii) *Barrage Maps.*—Specially printed on any desired scale to indicate the position of an artillery barrage at successive stages reckoned from the zero time of an offensive.

(viii) *Hostile Battery and Target Maps* are printed on any desired scale, usually the 1/20,000, to show the positions of hostile artillery. The map used must be gridded.

(ix) *Geological Maps* are useful for determining depths and directions in driving mining and countermining tunnels, for exhibiting water-bearing strata and the possibilities of artesian bores, for indicating suitable sites for dugouts and bomb-proof shelters, for marking spots where good road-metal and gravel are obtainable for road-making and concrete, for pointing out soils suitable for entrenchment and gun emplacement, and for various other purposes. They are not strictly speaking military maps, but are of great importance in modern warfare, in which the presence of the trained geologist is necessary.

(x) *Maps of Water Supply.*—All the available information as to water is printed on the face of the 1/100,000 map for this purpose.

(xi) *Message Maps.*—These were portions of large scale trench maps, on the back of which were printed a series of skeleton reports and messages. The sender could fill in details of position, numbers, ammunition, &c., and strike out irrelevant portions. They were often transmitted by dogs or pigeons.

(xii) *Identification Traces.*—These are not maps but pieces of tracing paper on which squares are printed to correspond in size with the squares of the large-scale maps. By numbering and lettering the squares to correspond with the map and tracing a small amount of detail, the sender could add any useful information and employ the trace to illustrate and amplify a report.

(xiii) *Administrative Maps.*—Maps of our own area required for administrative purposes, and usually prepared for the areas of Armies. These are preferably shown on a gridded map.

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§32. General Remarks on Military Maps.

109. *Preparation and Nature.*—Practically all the maps above had the outline in grey and the water in blue as a base upon which the special information was printed.

The grid is an essential feature of these 1/10,000, 1/20,000 and 1/40,000 sheets and the same reference identified the same spot on each scale. It would have been better if the same grid could have been applied to the 1/100,000 map, but this was not possible. Administrative Area maps were, however, prepared late in the war by reducing the 1/40,000 to the 1/100,000 scale and applying the grid. The ideal should be borne in mind in the future,—to have the same grid reference on all maps.

110. *Layers and Models.*—The adoption of layers is not peculiar to military maps, but on such maps only would the system be applied to large scales like the 1/20,000. Many sheets of this series were layered as the war proceeded and were found most useful. Models also were much employed on the 1/20,000 scale, but the use of models and large-scale layered maps must obviously be confined to trench warfare.

111. *Maps of the United Kingdom.*—In the British Isles the half-inch and one-inch have hitherto been used as tactical maps. The only special military map produced in England is that on the 1/20,000 scale, of which a certain number of sheets have been prepared for training in military areas. They are ordinary large-scale topographical maps, but may be held to be special military maps because they are gridded and have other information of military value added, such as the co-ordinates of trig. points. Plate VII is a portion of one sheet of this map.

112. *Air Maps.*—The question of special flying maps is very difficult. In the late war the ordinary maps were used,—the 1/250,000 or the French 1/200,000 for lengthy flights and the larger scales when small areas only were involved. Ten sheets of a special flying map of the theatre of war in France on the 1/250,000 scale were prepared from designs submitted by the R.A.F., the principal feature of which was a dark background with the detail shown in white, blue and red. They were, however, but little used and were not reprinted. It is evident that the preparation of special flying maps must be the work of years, and a consensus of opinion amongst aviators is apparently likely to arise only as the result of a slow evolution in which unpractical methods will be gradually eliminated.

§33. Conventional Signs on Military Maps.

113. *Military Signs.*—Plate XIV shows, with slight emendations, the conventional signs which were finally adopted in the late war for giving military information on Trench, Artillery and

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MILITARY CONVENTIONAL SIGNS TO BE USED ON TRENCH & ARTILLERY MAPS.

The Signs are drawn to suit 1:20,000 scale maps.

ENEMY WORKS

Batteries and Gun Emplacements: *
Signs to represent position of emplacement fixed by photography and clearly visible on the ground. On larger scales show actual shape if possible.
or (alternative)

Machine Guns:
In trench or communication
Isolated

Trench Mortar

Anti-Aircraft Gun

Dumps:
Supply
R.E. or Pioneer
Ammunition

Zone of Activity (hatched)

Huts

Dugout

do. Concrete

Searchlight

Tank Trap

Anti-Tank Gun

Lamp Signalling Post

Observation Post

Command Post

Aerodrome

Balloon

Telephone or Telegraph Exchange:
Main
Sub

Telephone or Telegraph:
Airline
Buried

Track

Obstacles:
Abatis

Wire Entanglement { On posts / Coiled

Chevaux de Frise

System of Trenches

Trenches (details):
Main line, character unknown

Organised for fire { Traversed / Recessed

Main Communication

Other Communication

Old, abandoned, etc.

From information other than photo

BRITISH WORKS

Same Signs in RED.

* An occupied emplacement is shown on Artillery maps by sign ● (1 Gun), unoccupied ○, overprinted in another colour.

Truscotts, London.

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Organization maps. The colours can of course be varied; the final practice was to print our trenches in red and enemy trenches in blue.

The symbols used by the Germans were not the same as those of Plate XIV, though on similar lines.

114. *Limitation of Symbols.*—Plate XIV does not include all the military symbols which were used or could be used: no plate of characteristics could be final. The topographical signs are omitted, since they were naturally chosen to suit conditions in France and Belgium only. British cartographers should adhere to the symbols of the Ordnance Survey for this country and should generally use the signs of Plate II for colonial and foreign topographical maps.

Plate XIV supplements the signs on Plate XVIII, which are intended for sketching. Though the former plate has been designed primarily for the map maker, the military symbols have been chosen with a view to clarity and simplicity and can be easily adapted by the sketcher. It may be found advisable to add a few others, but the number must be strictly limited, since a multiplicity of signs would defeat the object of the sketch.

In the representation of objects for which signs have been approved, no deviation from the authorized signs should be allowed. At the same time it must always be remembered that new conditions require new signs, and for this reason additions or alterations to signs will be constantly wanted. These should be made by the proper authority.

It is very important that in future wars the conventional signs to be used for military information should be clearly laid down and made known to the troops.

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PART II.

CHAPTER XI.

PRINCIPLES OF SURVEY.

§34. Basic Principles of Sketching and Survey.

115. *Survey and Sketching.*—This Manual is not intended to teach an officer to be a trained surveyor. The principles of sketching are, however, essentially the same as those of surveying, though the actual processes are of a vastly different order of accuracy.

It has, therefore, been considered desirable to preface the subject of sketching with a short outline of the principles of survey. A knowledge of such principles is, moreover, a great aid to the intelligent appreciation of maps.

116. *Basis of Survey.*—The basis of all maps which have any pretentions to accuracy is a series of *fixed points.* The positions of these points being known, they can be plotted on a sheet of paper, and they form an accurate skeleton, or network, to which the topographical detail can be fitted.

These points can be fixed in a variety of ways. For example, the distance between each point and those adjoining it might be measured on the ground. This, however, would be such a laborious and costly proceeding for any but the smallest areas as to put it out of the question where maps in general are concerned. Various means have been devised, therefore, whereby the necessary distances can be measured accurately, and at the same time quickly and economically. Of these methods the most usual is that of *triangulation.*

§35. Triangulation.

117. *Definition of Triangulation.*—Triangulation is the name applied to the system of covering an area with a network of triangles, for the purpose of measuring the distances between, and thus fixing the position of the points which lie at the angles of the triangles.

The triangle is used because it is the simplest of all figures, and its shape and dimensions can be determined with a minimum amount of measurement. Thus, if you know the length of one side of a triangle, and can measure any two of its angles, you can by a simple calculation determine the lengths of the other two sides, and of the remaining angle.

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It has already been mentioned that the accurate measurement on the ground of long distances on the earth's surface is a laborious and difficult matter. On the other hand, the measurement of angles is easy. With a proper instrument, called a "theodolite," it is possible to measure angles in a short time and with a high degree of accuracy.

Evidently, then, triangulation affords a very suitable method for fixing the skeleton of points of which we have spoken. From what has been said above, it is clear that we must measure the length of *one* side to begin with. Having done that, we can, by the comparatively simple and easy process of measuring angles, extend a system of triangles from this original side over a large area; and provided that proper precautions are taken, we can do this with a high degree of accuracy.

118. *Trig. Points.*—The first process then, in carrying out a triangulation, is to select and mark the points of the triangulation, since until they are marked no observations can be made from or to them; the second process is to measure the distance between two of the points and to determine its position and direction on the earth's surface; and the third to measure the angles at each point.

In practice these processes may be carried out in a different order, or they may go on concurrently; but it is convenient to consider them as above.

The points of the triangulation are called trigonometrical points, or, shortly, "trig. points." They consist as a rule of two features: a permanent mark, in metal or stone, which is often buried underground; and a visible signal vertically above this mark. Sometimes the signal is specially erected, and takes the form of a beacon, flag, cross vanes, or similar construction; sometimes it is an existing feature such as a church tower or steeple.

Trig. points must be selected so that it is possible to see from any one point to all the others between which angles have to be measured. For this reason they are usually placed on hill tops. There are certain other considerations affecting the choice and use of trig. points which will be mentioned later.

119. *Base.* The next step is to measure the length of one of the sides. As this forms the basis of all the subsequent measurements which are obtained by computation, this side is called the "base." It is of great importance that the measurement of the base should be carried out with the greatest possible accuracy, because any error in its length will be carried throughout the work, and owing to the accumulation of other small errors which cannot be avoided, the inaccuracy of subsequent sides is likely to be continuously increased. It is, therefore, measured several times, with every precaution to avoid error and to compensate for variations in temperature and conditions generally. The position of the base is chosen with care with a view to facilitating this accurate measurement, and also for the purpose of

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connection with the subsequent triangulation. Base measurement being a laborious process, it is usual to measure a comparatively short distance, and by gradually increasing the size of the triangles to arrive finally at a convenient size for extension over the country. This process is called the "extension of the base." Modern methods have made it possible to measure much longer bases than formerly, and this has simplified the process of extension—but the length of the base is still usually a good deal less than the average side of the main triangulation.

We have at the same time to determine the position on the earth's surface of the base, and its direction or azimuth. These are obtained by astronomical observation, by methods which need not be described here.

120. *Measurement of Angles.*—The carrying out of the triangulation is now a repetition of the process of angle measurement. The theodolite is set up at the two ends of the base, and at every subsequent trig. point, and a "round of angles" is measured to other visible trig. points. By this process each angle of every triangle is measured. The measurement of each angle is a necessary precaution, because every measurement, of whatever kind and no matter how carefully made, is subject to a certain amount of unavoidable error. Hence it is always found that the measurements of the three angles of a triangle (which we will consider for the moment as a plane triangle), do not add up to exactly 180°, as they should. The difference is due to slight errors in measurement, which have to be adjusted later.

Having obtained the angles of the triangles, the lengths of the sides of each are determined by a simple calculation, which is generally referred to as the "solution of the triangle."

121. *Orders of Triangulation.*—The above account gives an idea of the general scheme of a triangulation. We must now consider certain practical points connected with map-making.

In order to make a map we require, as will be shown later, a large number of fixed points at no great distance from each other (that is a few miles, or even only about a mile, apart). We could obtain these by making the triangulation that we have described consist entirely of small triangles; but there would be several disadvantages in this. As mentioned previously, every triangle contains a certain amount of unavoidable error. By making your triangulation system consist solely of small triangles the tendency is for these errors to accumulate too rapidly and in time to become serious. *Per contra*, large triangles conduce to accuracy.

The problem is, therefore, how to secure the accuracy given by a system of large triangles and at the same time to provide the necessary number of fixed points for map making.

The method adopted is to make a large governing or controlling framework of triangles of rigorous accuracy, and to develop from it subsidiary systems of smaller triangles. The various systems are called "orders of triangulation."

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122. *Breaking Down.*—We first make a primary system of triangulation, consisting of large triangles, for which we use large instruments with every precaution to ensure the highest accuracy. This system forms the foundation of the whole system of fixed points. We then make a secondary system of triangulation, consisting of smaller triangles, and using smaller instruments. This second order of triangulation is based on the first, that is to say, all or most of the first order points are included in the second order system. The same elaborate precautions to ensure accuracy are not required in this secondary system, because it is checked or controlled by the first order: fewer measures can be taken, and the work can be done more quickly. In the same way a third order of triangulation is based on the second, smaller triangles again being observed, and still less elaborate methods employed.

The scheme is thus to work from great to small, from the whole to the part. In each order of triangulation less accuracy is required than in the order above, because its limits of error are controlled by the higher order.

The tertiary triangulation probably provides points at the required distance apart for mapping purposes; but it may be found necessary to introduce a fourth order, though this is not common.

The process of dividing the area covered by large triangles into smaller is technically called "breaking down" the triangulation.

§36. Intersection and Resection.

123. *Intersected Points.*—It was mentioned above that in carrying out a triangulation it was customary to measure all three angles of each triangle. This is necessary when measuring triangles on which other work depends; as for instance in all primary and secondary work.

It is, however, obvious that if two angles of a triangle are known, the third is also known, because the sum of the three angles of a plane triangle amounts to 180°. If, therefore, we have measured two angles of a triangle, and have reasonable assurance that there is no serious error in the measurements, we can assume the value of the third, and so complete the measurements without visiting the third point. This method is occasionally adopted in tertiary or lower order triangulation, and may be done with safety if there is a check on the work, such as is provided for example, if the unvisited point forms the apex of two triangles. The method is commonly adopted for fixing points which it is not intended to visit; such, for example, as distant points, or any feature which may be useful for mapping purposes. Here again, the surveyor will always when possible check his work by observing such a point from three trig. points.

Points located in this manner are called "intersected points," because they are fixed by the intersection of rays observed from points previously determined.

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124. *Resected Points.*—There is another principle of survey, of a nature opposed to intersection, which is of the greatest value: this is "resection."

In intersection, undetermined and unoccupied positions are located by observations *from* fixed stations; in resection on the other hand, undetermined but occupied positions are located on the map by observations *to* fixed stations.

If the observations are made with an instrument like the theodolite and the resulting positions are computed, this method is sometimes known as "trigonometrical interpolation," and is capable of yielding very accurate results; if the measures are plotted directly (as from compass bearings), or are purely graphical (as on the plane table), the method is known by the more general name "resection."

This method is most useful when the fixed points are inaccessible, *e.g.*, church spires, and it has the further advantages of great saving of time and, unlike intersection, of necessitating a visit to the point to be fixed. It was largely used on the Western Front for fixing battery positions.

§37. Substitutes for Triangulation.

125. *Traversing.*—The above account describes the general principles and methods which are followed in carrying out triangulation. There are certain other questions involved in surveying to which it will be useful to refer briefly. The first of these is the employment of methods other than triangulation.

In certain exceptional cases triangulation may not be the most economical method of determining positions. For example, in certain areas of Africa which are nearly level and covered with dense forest, triangulation would entail the erection of enormous timber structures in order to see over the forest. In a case of this sort the method of "traversing" is adopted. A traverse is a connected series of lines on the earth's surface of which the lengths and bearings have been determined. Where precision is required the length of each line is measured with a chain or tape, and the angles between the lines are measured with a theodolite. A traverse of this sort was carried along the British front early in 1915, in the La Bassée area, and was invaluable in fixing points and controlling the map.

Another method, where large areas are concerned, and no greater accuracy is required than that necessary for a topographical map, consists in fixing a series of points by observation of their latitude and longitude. Here the position fixing is entirely independent of linear measurement of any sort. The observation of latitude presents no difficulty. That of longitude depends on facilities for comparing time, and is less easy; but it is certain that recent advances in wireless telegraphy will be of help in this direction.

126. *Trigonometrical Traverse.*—Under certain conditions a

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moderately good traverse may be run without either linear or astronomical measurement.

Thus, Fig. 14, suppose A B is the side of a triangulation and that accordingly the length of A B and the geographical positions of its extremities are known. Suppose also that it is required to run a traverse to G.

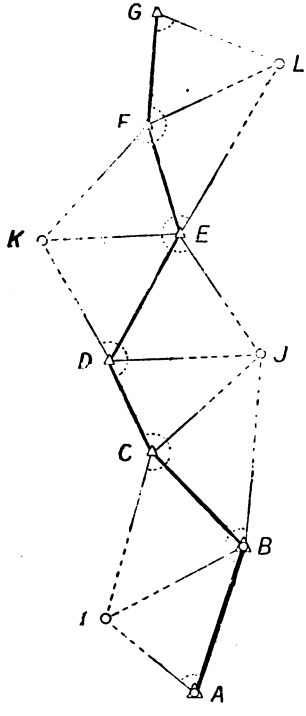

FIG. 14.

Let the stations of the traverse be A, B, C . . . G, and I, J, K, L, a series of intersected points. Then by measuring all the angles marked at the stations, the positions of all the points I, C, D . . . L, G can be computed. The method is obviously applicable to the plane table, though the accuracy is naturally much less than when the theodolite is employed.

The intersected points must have very definite apices, ought to be clearly recognizable from all directions around and must be chosen so that the triangles are "well-conditioned," that is to say, none of the angles should be less than 30° or greater than 150°.

As the triangulation is shown in the figure there is no check on the work. Additional intersected points ought, therefore, to be observed to control the accuracy of the observation and computation, both of which should be carried on concurrently; a mistake in an observation can be easily rectified only so long as the observer remains on or near the spot.

§38. Measures of Altitude.

127. *Heights by Angular Measures.*—In the angle measurements of which we have spoken we have so far dealt with none but horizontal angles, which are all that are required for the terrestrial measurement of *position*. In making a map, however, we must also take account of relative *height*, as a map which gives no indication of vertical relief is of little value, at any rate for military purposes.

Theodolites are usually provided with means for measuring vertical angles as well as horizontal, and it is customary to measure both when observing at a station. By measuring the vertical angle, that is the angle above or below the horizontal

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plane, to the distant point, knowing the distance between the two points, we can calculate the difference in height.

128. *Heights by Spirit Levelling.*—There is another means of determining differences of height, and that is by levelling. A "level" is a telescope with a very sensitive bubble attached, by means of which the telescope can be accurately set in the horizontal plane. Readings are taken on a vertical staff, on which are marked divisions of feet or metres, with sub-divisions of tenths and hundredths. Levelling is carried out over the area of a country in networks of lines, divided, like triangulation, into primary, secondary, tertiary and lower systems. The heights of the main points in the system of levels are marked by permanent recorders, called "bench-marks."

It should be clearly understood that a "line of levels" means a line of points the height of each of which has been accurately fixed, but which varies from point to point. The line chosen is arbitrary, and does not mean a line of points of the same level, which is a "contour" (*see* below).

The spirit-levelling system of a country is the basis to which all heights are referred, but it would be too expensive to carry the lines of levels to all trig., intersected and resected points. The measurement of vertical angles with the theodolite affords a simple and inexpensive means of measuring height difference of ample accuracy for all map purposes.

129. *Instrumental Contours.*—The system of lines of levels in a country is sometimes supplemented by the survey of a certain number of "contour lines." These are lines on the earth's surface following a certain definite level. They are traced by means of a level of simple form and marked by temporary pickets which are surveyed. Such contour lines have been surveyed in the British Isles, but few other countries have gone to the expense of fixing contours instrumentally.

§39. Cadastral and Topographical Surveys.

130. *Classes of Maps.*—The above paragraphs describe in a general way the processes which are common to nearly all surveys. From this point methods diverge according to the type of map which it is desired to produce.

Maps may be divided broadly into two classes:—

Cadastral Maps, the object of which is to show property boundaries and areas. To be of use these must be on a large scale, and rigorously accurate in plan; but the representation of vertical relief on such maps is of minor importance and is often omitted.

Topographical Maps, the object of which is to show topographical features, and to serve as guides for travelling, engineering or military operations. They are usually of smaller scale than cadastral maps, and the same rigorous accuracy is not essential; but they must show the ground forms.

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131. *Cadastral Methods.*—For the production of a cadastral map the usual process is to " break down " (*see* Art. 122) to small triangles, and then to map all necessary detail by chain survey. In the United Kingdom this consisted in measuring along the sides of the triangles, which were broken down to very small dimensions, and along numerous cross lines, and recording the points at which detail of any sort—road edges, fences, hedges, &c.—crossed these lines. Detail was also fixed by " offsets " from the measured lines—that is, short perpendiculars measured with an offset rod from the survey line to the detail.

The whole thus formed a network of tied measured lines to which the topographical detail was rigidly bound. The resulting map is an accurate plan formed by actual measurement on the ground.

In undeveloped countries less elaborate methods, more suited to the conditions, are employed ; but it would be out of place here to describe the methods in use in different countries.

132. *Topographical Methods.*—For a topographical map on the other hand, it is not necessary to break down to such small triangles as those of the United Kingdom, and the topographical detail is supplied, as a rule, by plane table survey. In this method the plane table is set up at various points, its position fixed by resection, and the topographical detail between these points fitted in partly by intersection and partly by drawing.

The resulting map is one which is sufficiently accurate for the general purposes for which it is intended (such as travelling, recognizing features, measuring distances), but which has not the same rigorous accuracy as a good cadastral plan. Detail close to trig. points will be exact, but in the spaces in between it will be subject to small errors varying with the amount of time and care it has been possible to put into the plane table survey. On this class of map it is essential to show the ground forms, since otherwise it does not fulfil the conditions of a topographical map. This is done by determining the heights of various points, usually by means of a " clinometer," and drawing lines on the map to represent contours. These lines, which appear on most modern maps, are often called contours, but strictly speaking they are " form-lines " ; that is they are sketched or drawn and not levelled and surveyed like a true contour. Form-lines, drawn by a skilled topographer while on the ground, are a sufficiently accurate representation of height differences for most military and practical purposes, except engineering works dependent on precise levelling.

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Chapter XII.

INSTRUMENTS.

§40. Simple Instruments.

133. *Drawing Instruments.*—As a rule, the only instruments which it is desirable to carry are pencils, rubber, protractor, and a pair of dividers, which for accurate work should be hair dividers. A pencil compass is often useful; and for more elaborate work fine pens and coloured inks may be required.

134. *Service Protractor.*—The rectangular service protractor, "A," Mark III, is illustrated on Plate XV, where the obverse and reverse are shown together. The protractor is of ivorine. 6 inches long by 2 inches wide exactly. On the front are found the following scales in British units :—

1/20,000, Primaries ...		¼ mile, Secondaries		...	.....
1/20,000	,,	... 100 yards ...	,,	...	20 yards.
1/100,000	,,	... 1 mile	,,	...	¼ mile.
1/100,000	,,	... 1,000 yards	,,	...	100 yards.
1/250,000	,,	... 1 mile	,,	...	¼ mile.
1/250,000	,,	... 1,000 yards	,,	...	200 yards.
2 inches=1 mile	,,	... 100 yards	,,	...	20 yards.

On the back in British units :—

1 inch = 1 mile, Primaries, 100 yards, Secondaries, 50 yards.
½ inch = 1 mile, ,, ,, ,, ,, ,,
Scale of inches, with diagonal scale for hundredths of an inch.

On the back in metric units :—

1/100,000, Primaries, 1 kilometre, Secondaries, 50 metres.
1/20,000 ,, 100 metres, ,, 20 metres.

The protractor, properly so called, is represented by the degree graduation along three edges of the front face. The point from which the rays are drawn is on the fourth (or zero) edge and is indicated by an arrow-head.

It will be seen that there are two sets of figures to these graduations—an outer set, reading from 0° to 180°, and an inner set reading from 180° to 360°. All readings being made clockwise, this arrangement is for the purpose of plotting bearings, which are always measured from north by east.

For a description of the use of the protractor, *see* Chapter XV, §56, Arts. 206–7.

135. *Pedometer.*—This is merely an instrument for counting paces. It is of more advantage in marching than in sketching, where the bases are short and the paces can be easily counted.

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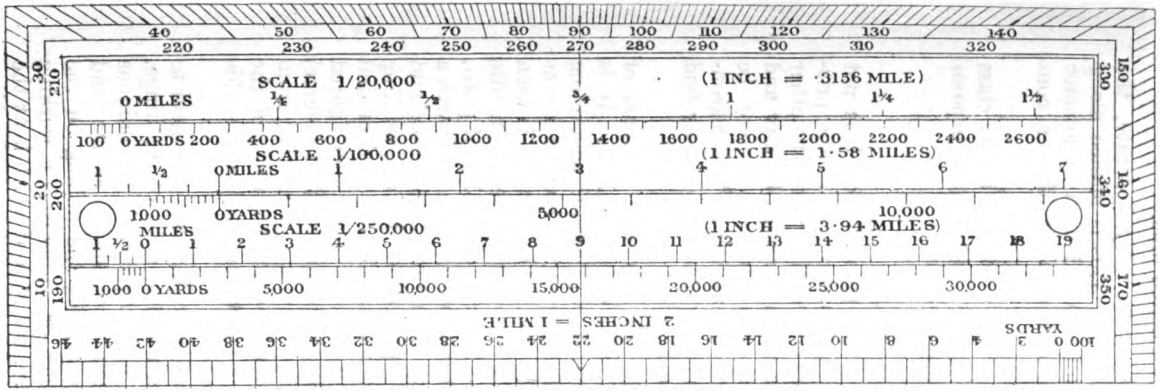

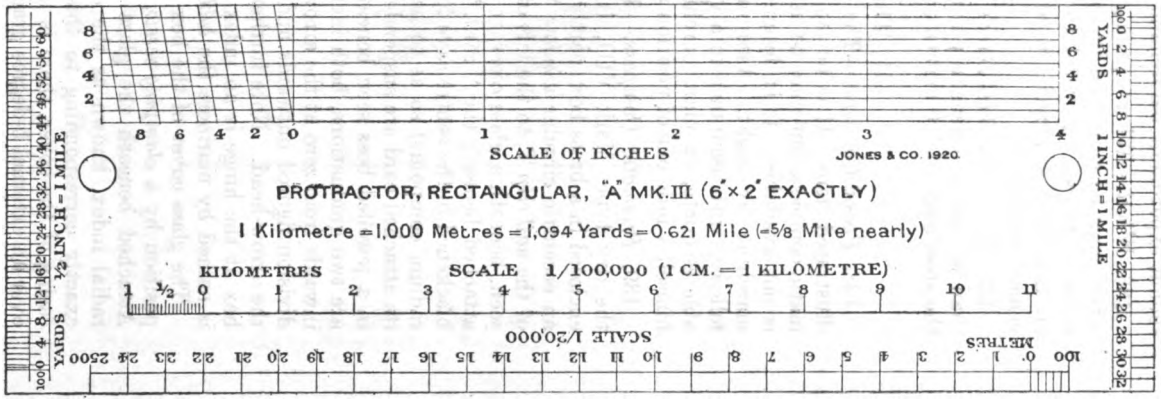
SCALE OF INCHES
JONES & CO. 1920.
PROTRACTOR, RECTANGULAR, "A" MK. III (6"×2" EXACTLY)
1 Kilometre = 1,000 Metres = 1,094 Yards = 0·621 Mile (= 5/8 Mile nearly)
KILOMETRES
SCALE 1/100,000 (1 CM. = 1 KILOMETRE)
SCALE 1/20,000
METRES
YARDS
½ INCH = 1 MILE
1 INCH = 1 MILE

PLATE XV.

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As an instrument for assisting in rendering road reports in unmapped or badly mapped regions its use can be recommended. The instrument can be adjusted to the pace of the traveller, who should experiment beforehand on a measured mile.

136. *Wheel.*—Where pacing is not sufficiently accurate, the wheel may be employed in certain cases. This is pushed along roads or tracks, the revolutions being counted by a cyclometer on the hub. A bicycle fitted with cyclometer is often a convenient substitute.

137. *Tapes and Steel Bands* are used in work of a higher class than we are here generally considering. For surveying purposes the steel band of 100 metres or yards is preferred.

§41. The Compass.

138. *Pocket Compass.*—The Watch Compass, Mark VI, is not illustrated here. It is not so refined an instrument as the prismatic compass, but may be used for map reading when the other is not available. It is designed for rough bearings by day and marching by night. Assuming that the direction cannot be followed with assurance to a greater accuracy than 5°—a reasonable estimate,—a man marching solely on the bearing may find himself a mile out of position after a 12-mile march.

139. *Prismatic Compass.*—The Service Prismatic Compass of the dry type, Mark VIII, is illustrated on Plate XVI. It is enclosed in a brass box, partly lacquered, with a lid C, containing an eccentric circular *window* W. Press open the box by means of the *nail clip* T, to the left of the handle. The compass is then seen, beneath a glass *cover*, to be of the " card " type, the needle attached beneath the " card." The latter is of mother-of-pearl, blackened in the centre save for an *arrow*, which is painted with a radium compound so as to be visible at night. The needle and its attached card are suspended on a pointed steel pivot, working in a jewelled boss seen beneath the cover. On the card or dial are two graduations, both increasing clockwise, the inner figured inwards from zero at the arrow-head, the outer and finer (degree) division figured outwards and starting from a zero at 180° from the arrow-head. Note further, that affixed to the inside of the box at the hinge is an index with a short vertical line L: this is named by mariners the *lubber line.*

The glass cover of the box can be rotated, unless it is held to position by a *clamping-screw*, J, seen to the right of the hinge. Attached beneath the glass near its periphery is a luminous radial index, known as the *direction mark*, shown as D; and exactly corresponding to this, interrupting the milling on the casing of the cover, there is an index, or *setting vane* I, working over an external 5-degree graduation, the zero of which is at the centre of the hinge, corresponding exactly to the lubber line within. On a second and lower external graduation are shown the *points of the compass*, N. under the hinge, N.W. (315°) near J on Plate XVI.

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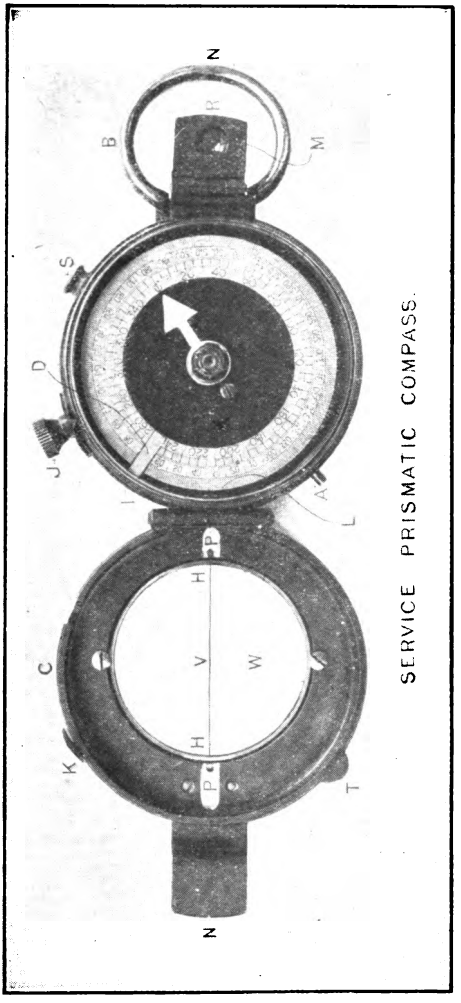

SERVICE PRISMATIC COMPASS.

PLATE XVI.

[*To face page* 84.

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The compass card during this examination has been motionless. Release it by pushing the *stop* S away from the ring handle. It will be noticed that this stop is automatically brought into action by closing the lid, the stop being thus moved towards the ring by the *cam-clip* K on the lid. The design is to lift the card and its boss off the point of the steel pivot, which otherwise would be liable to damage when not in use.

A *hair-line* H V H is engraved vertically on the window. In the casing and below the hair-line are two luminous strips P for sighting at night. Observe that in these strips are two small holes H, which are drilled through the window casing; if the glass is broken in usage, a horse-hair or thread can be passed through these holes as a substitute for the hair-line. A *tongue* forms an extension of the lid; notice the *notch* N at the end and the similar notch N on the ring handle.

Within the ring there is a small *magnifying prism* M, whose casing R is hinged to a slide in a shield screwed to the brass box. Tilt up the casing, thus revealing the eye-hole, above which the prism casing is slotted. When the hair-line H V H is vertical, the edges of this *sighting slot* ought to be seen to be parallel to it and are so in a well-constructed instrument.

It will be found that, for focussing the prismatic magnifier, it is necessary to draw up the prism; for this purpose a *slide* attached to the prism casing is provided to work in a groove in the shield.

140. *Observing with the Prismatic Compass.*—To make an observation with the prism, pass the left thumb through the ring, place the left forefinger underneath the box, the right thumb on the stop and the right forefinger on the tiny stud A at the left of the hinge, which actuates a *check-spring* in the box and so brings to rest the oscillations of the needle. The hair-line must be vertical. Observe it through the sighting slot, keep it vertical against the object to be sighted and at the same time observe the readings of the card. At the mean of the two readings of the oscillation press the check-spring pin to bring the needle to rest. Then free it and allow the card to settle at the required bearing, which may then be read to a quarter of a degree if the hand be steady.

The compass may also be read directly but much less accurately by means of the inner graduation on the card and the lubber line. Open the lid out flat. The *axis of the compass* NLHHN is now the line passing through the notch in the ring, the centre of the compass, the lubber line and the notch in the tongue. Direct the axis towards the object and read the inner figuring on the card against the lubber line.

Next turn the glass cover until the setting vane indicates the bearing of the object above on the external graduation of the box. Clamp the cover at this bearing by the screw J, and again direct the axis towards the object. It will then be seen that the luminous direction mark on the cover is exactly over the arrow-

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head on the card. The compass is then *set* for night marching on this particular bearing; if you preserve the direction mark and arrow-head in coincidence and move in the direction of the axis, you will be moving in the line of bearing indicated by the setting vane. The direction of the required movement is clearly indicated at night by the luminous terminals of the hair-line.

Note, finally, the rubber ring on the base of the box, which prevents the compass from slipping when on a smooth surface.

141. *Liquid Compass.*—It is probable that the Mark VIII compass will soon be superseded by a compass of the liquid type. The advantage of this type is that the card, being immersed in liquid, comes to rest very much more quickly than in the ordinary compass. It is therefore unnecessary to provide a check-spring and stop. In other respects the compass is generally the same as Mark VIII, but a few points may be noticed.

The outer graduation on the card is transparent. A luminous patch on the bottom of the box beneath the erected prism emits rays which illumine the graduation at night. On the glass which seals the liquid there is another luminous patch near the hinge; on this horizontal patch the lubber line is drawn. The setting circle is etched on the upper glass, whose cell is milled and rotates as in the dry type. The bearing is then set for night marching by bringing the desired reading on the upper glass into coincidence with the lubber line. (Note that in this graduation (5°) the short division traces correspond to the figures.) There is, however, a setting vane for use with the points of the compass, which form the single external graduation; corresponding to this setting vane there is as before a luminous direction mark on the rotatable upper glass.

If bubbles form in the liquid, trap them by turning the box obliquely over.

142. *Plane Table Magnetic Compass,* usually known as the *Trough Compass.*—A 5-inch magnet is poised centrally in a narrow rectangular metal box, with glass face. The ends of this box are removable, and fold over the glass face in order to keep it in position. The south-seeking end of the needle is provided with a small sliding collar by means of which "dip" is counteracted. On metal plates at both ends of the box there are engraved five degree divisions on either side of zero, which marks the lubber line; and an adjustment is provided whereby the needle is made to read equally on either zero. The side of the metal box is parallel to the line of zeros, *i.e.*, the axis of the compass, and in the working position is brought by the adjustment into parallelism with the axis of the magnet. A brass pin actuates a lever in the box which checks the swing and the wooden case for the compass box has a sliding lid so designed that when pushed home it presses this pin and raises the needle off its pivot.

143. *Dip of the Compass.*—If a magnetic needle be suspended

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freely, it will, besides pointing to magnetic north, take up an inclination to the horizontal which varies with the locality. This inclination is called the *dip*, and is compensated by a small weight. A needle which is balanced for dip in Great Britain will be found to be out of adjustment in another part of the world where the dip is different. It can be corrected by affixing a small weight, *e.g.*, sealing wax or tinfoil. Plane table (trough) compasses are usually provided with a small sliding collar for this purpose.

A few examples of the present amount of the dip, which changes like the variation, will illustrate the values in different parts of the earth.

Kew	67° N.	Dar-es-Salaam	37° S.
Dehra Dun, India	45° ,,	Cape Town	66° ,,
Toungoo, Burma	23° ,,	Melbourne	68° ,,
Kodaikānal, India	4° ,,	Winnipeg	78° N.
Helwan, Egypt	41° ,,	New Orleans	61° ,,
Kodok, Egypt	0° ,,	Jamaica	48° ,,

The line of zero dip is the magnetic equator.

Irregular remagnetization will upset the balance of a needle. This, which must also be compensated by readjusting the counterpoise, should not be confused with dip.

The student may consult:

The Prismatic Compass and How to Use it. By Paul Dériaz, revised by Major A. D. St. G. Bremner, M.C., R.E. London: E. R. Watts & Son, 1917.

§42. Table Instruments.

144. *Cavalry Sketching Board.*—A small board (of working surface $7\frac{1}{4}$ inches by $5\frac{1}{4}$ inches) compactly fitted with a pair of rollers, a small magnetic compass, a clinometer and a strap for attachment to the fore-arm; it weighs about $1\frac{1}{2}$ lb.

The two rollers are fitted to opposite sides of the board and enable a long strip of paper, $7\frac{1}{8}$ inches wide, to be carried, the paper being unwound from one roller and wound up on the other as the sketch progresses; a simple device regulates the friction of the roller bearings. Two scales are stamped on the board, viz., 2 inches to 1 mile with secondaries of 20 yards and a scale of inches with secondaries of 0·02-inch.

A compass box is sunk in the face of the board and is free to revolve in a fixed brass collar. A fine index line, marked on the glass cover of the compass box, can be set to any position by revolving the cover.

The clinometer, which is set in the back of the board, consists of a simple pendulum, protected by a sheet of celluloid. The pendulum is normally clamped, but can be freed by pressing a small projecting knob. The clinometer sights consist of two projecting screws on the edge of the board and are adjustable.

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145. *The Plane Table.*—The plane-table is merely a portable table on a tripod stand, Plate XVII. The board or table proper, dismounted from its stand in carrying, is fixed to it in working, and can then be revolved so as to " set " the sketch.

The portable pattern is 18 inches square and has telescopic legs. The R.E. pattern is 18 × 24 inches, with rigid legs. Both are provided with waterproof covers.

The adjuncts to the plane table are the trough compass, previously described, the sight rule and the clinometer. These latter we shall now describe.

146. *Sight Rule* (16 inches).—A solid ruler, seen on Plate XVII, provided with a hinged sight-vane at each end. The edges are steeply bevelled and are stamped with two scales, viz., 2 inches to 1 mile reading to 50 yards and extending to 10,000 yards, and a 12-inch scale fully divided to 0·02 inch.

The rear sight-vane is provided with a narrow slot, while the fore-sight is hollow and carries a fine vertical wire or horse-hair stretched between two small holes and secured by screws. The sight-vanes fold down to rest in recesses cut on the top of the ruler, but in the working position are at right angles to the latter. For work in hilly country, where rays are often steep, a fine thread may be tautly stretched from one sight-vane to the other, holes being cut at the top of the vanes for this purpose.

The sight rule is in a leather case with a pair of straps for attachment to a plane-table tripod. The weight in case is 1 lb.

Telescopic alidades and optical sight rules are employed in some extended surveys, but are outside the scope of this manual.

147. *Clinometers.*—Clinometers are made of three general types. The first type is represented by the *Service Clinometer*, the clinometer on the Cav. Sketching Board, and the *Watkin Mirror Clinometer*. Here a small pendulum in a flat cylindrical case gives the vertical, with reference to which the slope is read on a scale of degrees.

In the second type, represented by the *Abney Level*, a small level is used. The latter is attached to a vertical graduated arc, rotating on a horizontal axis forming a transverse attachment to a small telescope. As an image of the bubble is seen in the field of view of the telescope when the level is horizontal, the instrument is very convenient to use and is much more accurate than the clinometer of the first type. A scale of gradients sometimes accompanies the degree scale.

148. The third type of instrument is represented by the *Indian Clinometer*, Mark IV, adapted for the plane table (*see* Plate XVII).

It consists of (1), a base plate, 9 inches long, with three studs constituting its feet; (2) the level arm, hinged to an end of the base plate and provided with a mill-headed screw, bearing on the base plate, by means of which it can be levelled; (3) and (4), two vanes, hinged to the level arm at its extremities, and maintained in upright working position by steel springs. The rear vane,

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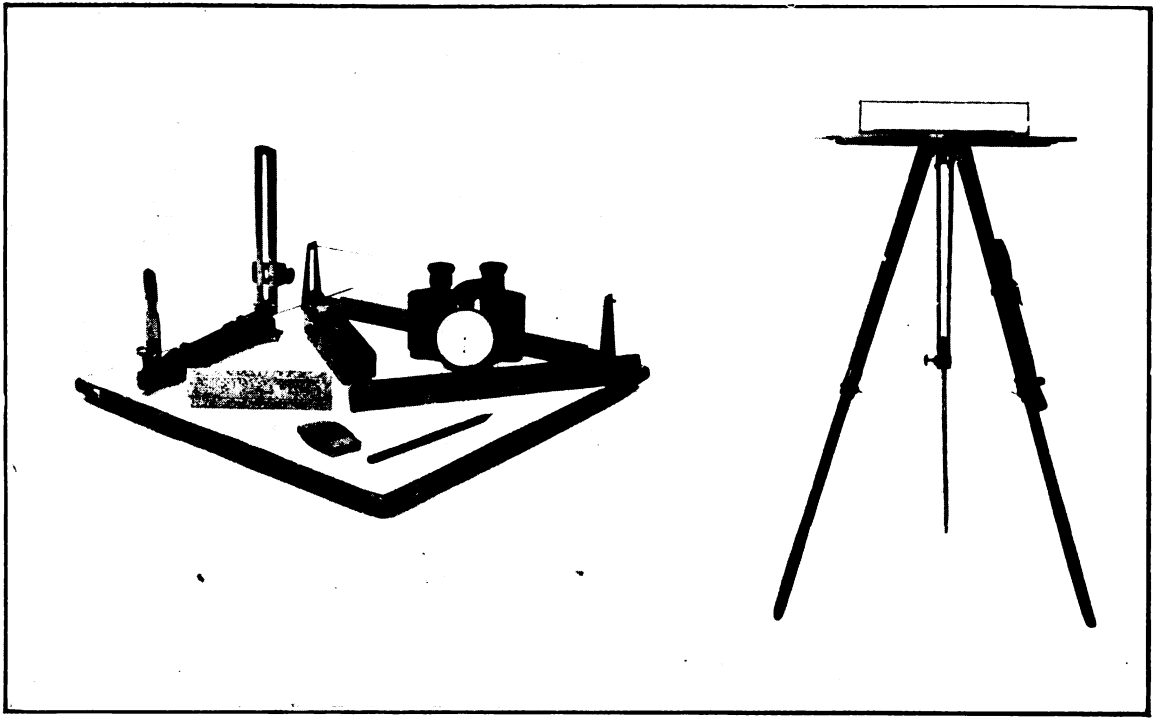

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PLATE XVII.

Sight Rule, Trough Compass, Clinometer, Aneroid, &c. **Plane Table.**

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4 inches long, is pierced by a peep-hole, forming the backsight. The forward vane, 8 inches long, is slotted centrally and on the left edge of the slot is engraved a scale reading to 20 minutes directly. The zero of this scale is at the same height as the backsight, and the graduation extends upwards and downward to over 20°. On the right edge is another scale, graduated and figured with the tangents of the corresponding graduations of the degree scale, and reading direct to 0·005.

Angles are read by means of a fine wire which is moved up and down the forward vane by a rack and pinion. The weight in case is 2¼ lbs.

§43. Aneroid Barometer.

149. *Description.*—For sketching, 2½- or 3-inch aneroid barometers are recommended, graduated respectively to about 6,000 and 10,000 feet. The effect of changes of pressure on the vacuum drum is recorded on the circular scale of a dial.

On surveying types of aneroid there are two scales. The inner, a fixed scale uniformly graduated, records the atmospheric pressure in inches and reads directly to 0·05 inch. By turning a small screw at the back of the box, the needle can be set to correct pressure on this scale by comparison with a standard mercurial barometer.

The outer scale is known as the height scale, which is graduated according to some formula adopted by the maker. This scale is cut on a ring which can be rotated by twisting a milled head similar to the winding knob of a watch. In another design the movable ring carrying this scale forms the upper part of the casing, the periphery being milled for turning by hand, as in the setting circle of the prismatic compass. The scale reads directly to 50 feet, or closer by estimation, and is graduated from 0 to 10,000 feet. The instrument with its leather case weighs ¾ lb. in the larger pattern.

150. *Reading Heights on the Aneroid.*—The aneroid is usually described as *compensated* for temperature; this compensation, however, can never be perfect. The instrument for other reasons cannot be considered accurate beyond two-thirds of the limit of the engraved altitude, say, 6,500 on a scale of 10,000 feet. Within this limit, however, if the observer is fully informed, it is very valuable as an indicator of relative heights, which with a good instrument may be obtained correctly to 25 feet or less when all corrections are applied and full precautions taken. For absolute heights, *i.e.*, above M.S.L., it is less reliable unless one of the stations in the area surveyed is on the coast and frequent observations are made thereat.

The barometer should invariably be held in the same position, say face upwards, when the reading is made, and the case should be lightly tapped beforehand with the finger nail or a pencil.

The needle *lags* when the aneroid is moved rapidly from one station to another of different altitude, so that if read immediately

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on arrival the difference of height may be 5 per cent. too small, though commonly less than this. Allow it 10 minutes to settle, tapping gently each five minutes.

Measures may always be improved if the movements of a standard barometer are observed at a station temporarily fixed in the area and the corresponding corrections are applied to the readings of the travelling instrument. Of even greater value are stations, such as trig. points, of well-determined height, with which the reading of the instrument can be frequently compared.

Atmospheric pressure has a *diurnal variation* (atmospheric tides) of from 0·05 to 0·1 inch of mercury, being maximal at 10 A.M. and P.M., and minimal at 4 A.M. and P.M. During the day then a barometer at rest will show altitudes varying as much as 100 feet, even though the weather may not change.

Atmospheric pressure, reduced to sea level, varies in different places and from one month to another. Lines of equal S.L. pressure are called *isobars*. If a traveller on a horizontal plain crosses isobars, his apparent heights will change; it is possible in going up a river to appear to be proceeding down hill. In January isobars are closely packed in Tibet, the eastern coast of Asia and the western coast of British Colombia, particularly at Prince Rupert. In July, similarly, isobars are drawn together in Patagonia and Persia.

151. *The Common Aneroid.*—If the sketcher has an aneroid without an altitude scale he may compute differences of height approximately as follows:—

Let B_1 and B_2 be the pressures in inches at the lower and upper stations respectively. Then the difference of level in feet is

$$[2095 - 20\,(B_1 + B_2)] \times (B_1 - B_2).$$

Thus if $B_1 = 29{\cdot}87$ and $B_2 = 27{\cdot}33$, the difference of level is
$[2095 - 20 \times 57{\cdot}2] \times 2{\cdot}54 = 2{,}416$ feet.

For much useful information on this subject, together with tables of corrections, see *Hints to Travellers*, Vol. I, published by the Royal Geographical Society.

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Chapter XIII.

CONVENTIONAL SIGNS FOR MILITARY SKETCHING.

§44. Map and Sketching Signs.

152. *Map Signs.*—In Chapter IV some account has been given of the conventional signs used by the map-makers and Plate II gives the symbols used by the Geographical Section of the General Staff. We have seen that the nations of the world use different symbols, and it is necessary to learn the symbols for any given map or series of maps. Plate XIV gives the symbols used for military features on large scale maps at the close of the war in France.

On both Plates II and XIV the symbols and lettering are in many cases of a kind which can be drawn or written by a trained cartographer alone, whilst the essential requisites of lettering and signs for sketching are that they should be quickly drawn and plainly legible.

153. *Sketching Signs.*—The symbols on Plate XVIII have been selected from this point of view and should be adhered to. The plate is not exhaustive, nor could it be. If other symbols are required, they can be selected from Plates XIV and II. It is, however, better to write descriptions in language which cannot be mistaken than to crowd the sketch with symbols which are likely to be misunderstood. These descriptions should either be written on the face of the sketch, or, if the spot is already overburdened with detail, carried to the margin on the point of an arrow-head.

§45. Specific Symbols for Sketching.

154. A *Road* is drawn with continuous lines when it is enclosed by a fence, ditch or other obstacle and with dotted lines when unenclosed. When, however, all roads on a sketch are unenclosed, it is simpler to draw them in firm lines and make a note that they present no obstacle.

It should be noted whether a road is metalled or unmetalled, and usually it is desirable to give its width. Thus, 14′ *m* would mean a road the metalled portion of which is 14 feet wide, which will allow of two lines of traffic in opposite directions; less than 14 feet will not. Metalled roads suitable for traffic at all times should be coloured brown. If no colour is available, write "metalled" or "unmetalled" against each road.

All information as to the state of the road is most valuable; it should particularly be stated whether it will be liable to be cut up in bad weather.

A *Railway* is shown by a continuous, thick, black line with cross-bars; the words "single" or "double" should be written

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along it as the case may be. *Light Railways* or *Tramways* should be shown by a similar sign drawn narrower and lighter. Whenever there are railways of more than one gauge on a sketch, the gauge of each should be written.

A *River* is drawn in blue, with its name written along its course, and the direction of its current indicated by an arrow. The width of the river, and any further information as to the bottom and banks required to show its nature as an obstacle should be noted on the sketch. The bed of a river or stream which is dry at the time of sketching should be shown in black, a note as to its liability to flood being made on the sketch.

A *Bridge* should have its nature indicated by the word "iron," "stone," "wood," "suspension," or such like. The principal dimensions of important bridges and their suitability for heavy traffic should be stated.

Cultivation is denoted by inserting in writing the nature of the crops. If they present any obstacle to the advance of troops, or afford cover, a note to that effect should be added; but such information should be given only if required by the object of the sketch.

In the case of *Woods* it should be noted in writing whether they are passable for troops of all arms or not; their nature, whether of fir, oak, &c., and the degree of cover which they afford should be stated.

Heath, Heather or *Marsh* is shown by writing the word in black. When finishing up the sketch, the conventional sign shown on the Plate may be added if time permits.

Villages.—The Plate makes a distinction between scales of 4 inches to a mile and smaller scales. The distinction is rather arbitrary, and it is open to the sketcher to show details of villages on smaller scales if they would be useful for the purpose in view and if the scale, time and his own skill permit.

Form-Lines and *Heights* are drawn in brown and red. Form-lines should be shown by almost continuous lines, broken occasionally by very short spaces and dots where the hand requires a rest.

Troops.—It may be necessary to show the disposition of troops on a sketch; as, for instance, when making proposals for the distribution and action of a given force. It is not desirable to spend time in drawing troops in any form to scale. It is sufficient to draw a symbol which will attract attention, the necessary information as regards strength and unit being written alongside or in the margin.

In outpost sketches, the letters P, S, R, may be written instead of "piquet," "support," and "reserve."

The direction of a *patrol* is shown by an arrow.

155. The *Conventional Colours* are shown on Plate XVIII. For rough work, coloured chalk may be used. If no colours are available the symbols must of course be in black and any necessary explanations must be added.

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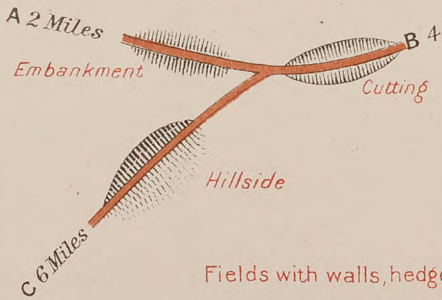
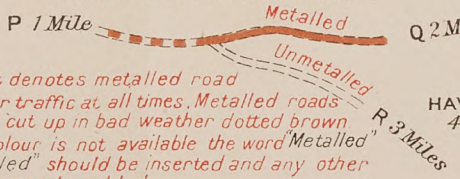
CONVENTIONAL SIGNS & LETTERING USED IN FIELD SKETCHING

Note: Words which should appear on the Sketch are shewn in black

Road enclosed by hedge, fence, ditch, or obstacle of any kind



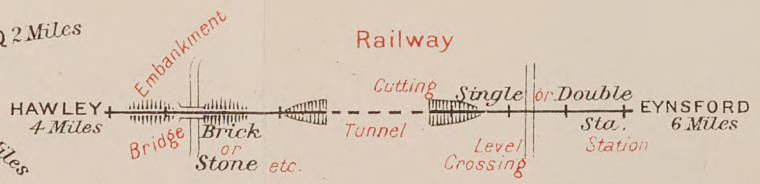
Road without fence etc.



Brown tint denotes metalled road suitable for traffic at all times. Metalled roads likely to be cut up in bad weather dotted brown. If brown colour is not available the word "Metalled" or "Unmetalled" should be inserted and any other necessary remarks added.

Footpath

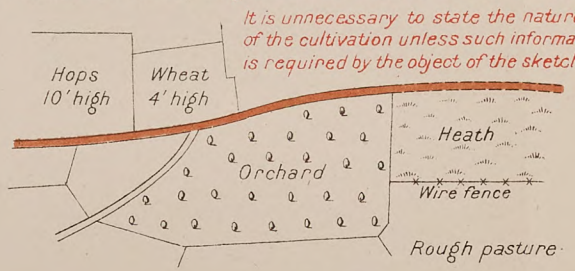
Railway

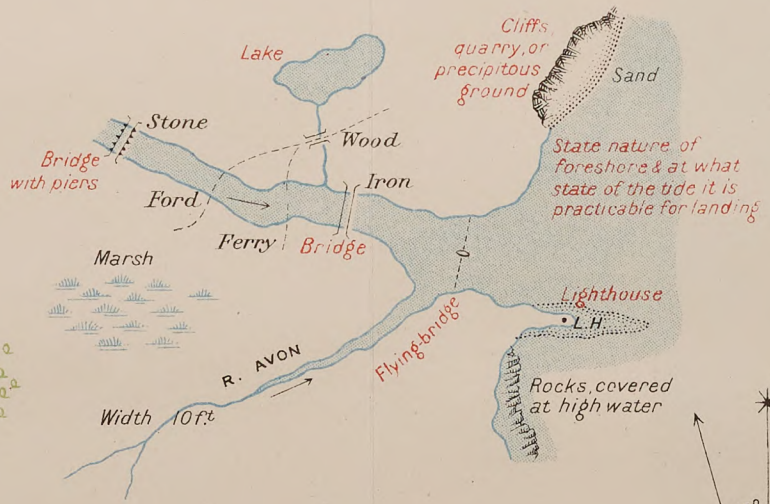


When there is not sufficient time to draw the cross-bars, a railway may be shewn by a broad black or red line with the word "Railway" written along it.

Fields with walls, hedges, fences, ditches or any obstacle

It is unnecessary to state the nature of the cultivation unless such information is required by the object of the sketch





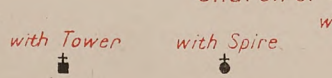
Wood

Nature of wood to be given in writing thus "Oak" "Pine" etc. and whether passable or impassable and by what arm, also the value of the wood as cover

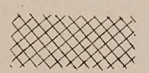
or or

if colour available

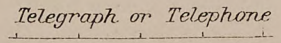
Church or Chapel



Obstacles



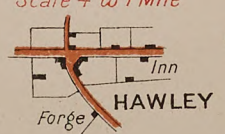
Telegraph or Telephone



Entrenchments

Villages

Scale 4" to 1 Mile

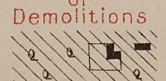


under 4" to 1 Mile

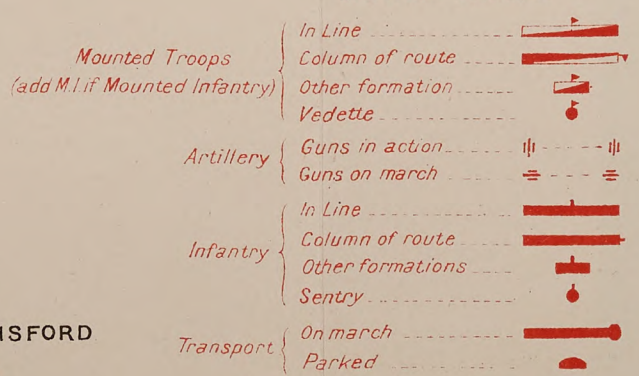
ABBREVIATIONS

P. ..... Post Office
T. ... Telegraph ,,
S.P. ..... Sign Post
o W. ..... Well

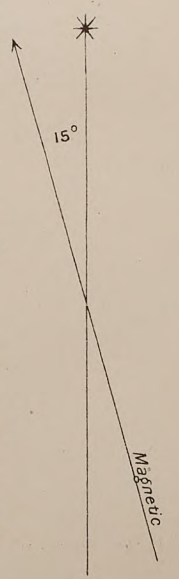
Clearance or Demolitions



BRITISH TROOPS



Opposing Forces coloured blue



G.S.G.S. No 2960

War Office, Aug. 1920

Truscotts, London.

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§46. Lettering.

156. Whatever lettering appears on a sketch must be easily legible, should not interfere with the detail, and should show clearly to what it refers. These are the only essential conditions.

Plate XVIII shows the lettering recommended for instruction. Students should be taught to keep the lettering of each style to a certain definite size and to write the signs, names and figures as neatly as possible. In actual practice, however, it is within the power of all officers to adopt and use some simple style of lettering which shall be clear and quickly written. The student not otherwise instructed may found his style of lettering on the Egyptian, upright or sloping, capitals and lower case, or the Stump writing shown on Plate II, should he discover that this style of lettering yields itself more readily to his hand than the Roman hairlines introduced to a limited extent on Plate XVIII.

No letter should be connected with its neighbour. The principal words, such as the names of towns, villages and rivers, should be in simple block letters.

All lettering should be horizontal, excepting the names and directions of rivers, railways, roads, and canals, which should be written along them; words descriptive of the nature and condition of a tract of country should be written so as to extend, as far as possible, over the portion of ground described.

For further remarks on this subject *see* Chap. XXII, Art. 319.

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Chapter XIV.

PLANE TABLE SKETCHING.

§47. Graphic Triangulation.

157. *The Method.*—The process of plane tabling will be described in considerable detail because the plane table is the most useful instrument for teaching the student the principles of sketching, which are much the same whatever instruments are employed.

The plane table is the most accurate instrument generally employed in making maps and sketches. It is equally useful for filling in the detail of precise surveys which are based on triangulation, or for making a map or sketch from start to finish. In the latter case it is necessary to measure a base and to execute a graphic triangulation. Such a triangulation will be substantially accurate for small areas, but if the map covers a large area the lack of a properly executed triangulation will involve considerable errors. It is only in systematic surveys that trigonometrical points will be available, and in sketching it will always be necessary to measure a base and to provide the necessary fixed points by graphic triangulation.

158. *Selection of Base.*—This should be on level ground. It should occupy a fairly central position, though this is of no great importance. Both ends of the base should be visible from well-marked natural points in the area to be surveyed, and from each other. The length of the base would usually be from half a mile to 1 mile, but the longer the better. A good rule is that the base should be about 2 inches long on paper; but this is longer than can usually be obtained. If possible, mark the ends of the base; or, if this cannot be done, measure between existing points or objects; or else measure in the same line as two existing objects. A base is usually selected on high ground because its ends then afford good points of observation. In some districts, however, where the higher ground is much wooded, and gaps are short, it is often better to select a base in an open valley. From this the prominent features of the hills on each side can be more easily fixed; and, when fixed, can be used as stations to fix detail in the valley.

Measurement of Base.—This must be done by careful pacing, or better, with a tape or wheel if available; the accuracy of the triangulation depends on the correctness of the base.

§48. Fixing Points by Intersection.

159. *Procedure.*—Call the ends of your base *a* and *b*, Fig. 15, representing two points A and B on the ground.* Select a third

* Throughout this discussion a small italic letter of the alphabet on the sketch will represent the capital of the same letter in nature.

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point C, visible from A and B, and in such a position that the triangle A B C will be as nearly as possible equilateral. This point will be *c* on your sketch. If you can now describe on *a b* a triangle *a b c* exactly similar to the triangle A B C in nature, the position of C will be fixed. This can be done by visiting A and B in turn and measuring the angles C A B and C B A graphically. The procedure is as follows :—

Set up the table at A, lay your sight rule on the paper so that

FIG. 15.

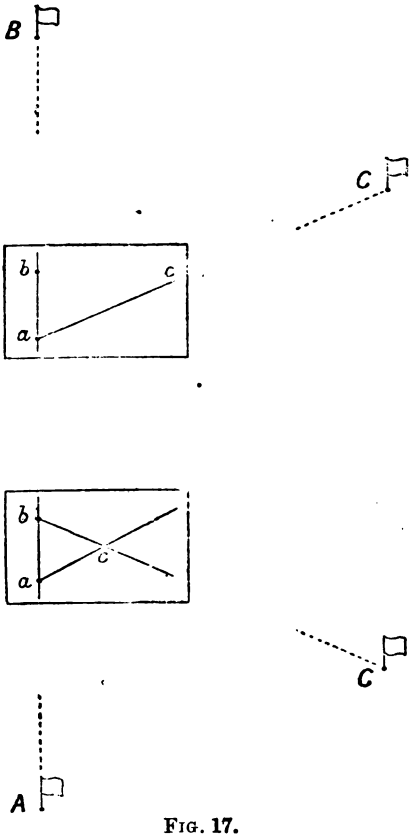

FIG. 17.

FIG. 16.

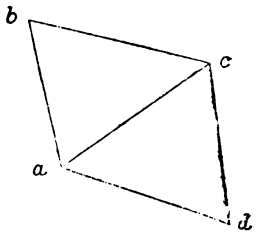

FIG. 18.

its edge lies exactly along *a b*, the back sight being towards *a*. Unclamp and revolve the table top, without touching the sight rule, until the sights are directed on B. Clamp the table top. Sometimes the action of clamping gives the table top a slight twist, and the eye should be kept to the sights until this operation is completed. We now know that *a b* is parallel to A B, and, therefore, that the sketch is set ; *vide* Fig. 15. (At this stage remove the trough compass from its wooden box, place it on

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the table in such a position that it reads zero and draw a line "compass rectangle" on your sketch paper completely round the compass. You now have a ready means of setting your table approximately* on any future occasion.)

Without moving the table top, pivot the edge of the sight rule about *a* until the sights are directed on C. (This operation can be effected readily by cutting the butt end of a pencil to an edge, as shown on Fig. 16, holding the pencil with the right hand so that the butt is on the table and the edge is vertically over the point *a*, and pivotting the sight rule against this edge with the left hand. It is assumed that a sight rule without a parallel arm is used.) Draw a straight line along the edge of the sight rule and name this line *a c*, since it is parallel to A C. When a line on the sketch is considered as representing a direction it is generally called a "ray." Since the rays *a b* and *a c* are respectively parallel to A B and A C, the angle *b a c* must be equal to the angle B A C.

Now proceed to B and in a precisely similar manner obtain the rays *b a* and *b c* parallel to B A and B C, as in Fig. 17. Then since the angles of the triangle *a b c* are equal to those of the triangle A B C the points *a b* and *c* are correctly placed on your sketch, and we know the lengths of *a c* and *b c*.

In a similar way we can select another point D and construct a triangle *a c d* as in Fig. 18. In this case it will not, of course, be necessary to measure the distance A C on the ground.

If D be visited and the table be set by the ray *d c* it will be found that the ray *d b* will pass through B and the ray *d a* through A.

Proceeding in a similar manner, a number of controlling points can be fixed all over the area to be sketched. This is "graphic triangulation."

160. *Illustration.*—The firm lines in Fig. 19 show an imaginary triangulation scheme, the numbers denoting the order in which the stations would be visited. The pecked lines represent check rays. In this figure the rays emanating from a point are drawn after they have left the point about one-tenth of an inch, and are then continued right up to the point which they are intended to fix. In practice it is inconvenient to have long rays covering the sketch; they would only be drawn of sufficient length to ensure an intersection.

161. *Case of Points not Mutually Visible.*—Sometimes it will happen that a point which it is desired to use is not visible. Suppose, for instance, that we wish to fix a point E, Fig. 20, by means of the triangle B D E, when B and D are not mutually visible. If we set the table at D by means of the rays *d a* or *d c* we know that the ray *d b* will point to B; and if we draw the

* Note the word *approximately*. In general in plane tabling, reliance should not be placed on the compass for orientation when other means are available. The compass, however, always provides a valuable check against the commitment of large errors.

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ray *d e*, the angle *b d e* will be equal to the angle B D E. Similarly by setting the table at B by the rays *b c* or *b a*, we can draw the

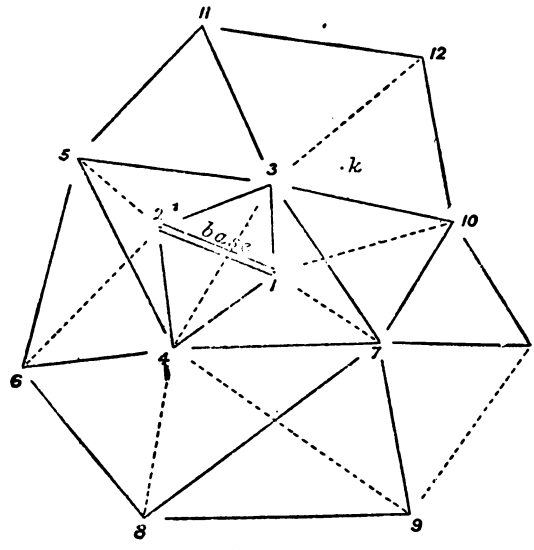

FIG. 19.

ray *b e* and obtain the intersection *e*. It will thus be seen that in order to draw a ray to any point it is only necessary that the table be correctly set. Theoretically, it does not matter what rays are used for the setting, but in practice the longest available ray should be used.

162. *Good Intersections.*—In order to obtain a good fixing, the intersecting rays should not meet at a sharp angle. In Fig. 21 the intersections marked *g* are good, *f* are fair and *b* bad.

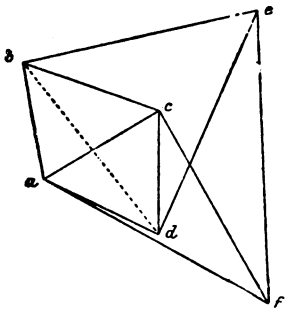

FIG. 20.

Theoretically two intersecting rays will fix a point, but in order to guard against error, it is advisable, except in the immediate neighbourhood of the base, that an intersection should be checked by a third ray.

It is especially necessary to fix with the greatest possible accuracy points which are subsequently to be used for resection. In fixing the main controlling points it is desirable to cover the area with long-sided triangles, and to interpolate points at closer intervals. Many points will be required in addition to the main control. The fixing of these points is called "breaking down the main control."

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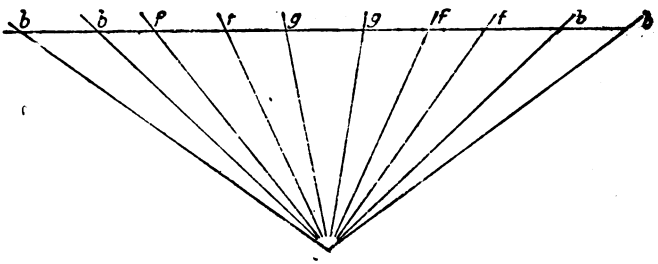

FIG. 21.

§49. Resection.

163. *Definition and Methods.*—This is the name given to the various methods of fixing your position from previously fixed points without actually visiting these points. It affords the chief means of breaking down the main control and of filling in detail.

The four chief methods of resection in order of accuracy are:

(*a*) From three fixed points without the aid of tracing paper.

(*b*) From three fixed points with the aid of tracing paper.

(*c*) From two fixed points by visiting two unfixed points.

(*d*) From two fixed points with the aid of the trough compass.

(*a*) *Resection from three fixed points without the aid of tracing paper.*

164. Set up the plane table at any point from which three previously fixed points can be seen. Orient the table by the trough compass, and from the three fixed points draw back-rays. If these three rays pass through a point, this point is the required position. If they do not pass through a point the rays will form a small triangle called the "triangle of error." The true position is now to be determined by the following rules:—

(i) If the triangle of error is inside the triangle formed by the three fixed points, the position is inside the triangle of error; and if outside, the position is outside the triangle of error.

(ii) In the latter case the position will be such that it is either to the left of all the rays when facing the fixed points, or to the right of them all. Of the six sectors formed by the rays, there are only two in which this condition can be fulfilled.

(iii) Finally the exact position is determined by the condition that its distances from the rays must be proportional to the lengths of the rays; *i.e.*, the position on the sketch must be nearest to that side of the triangle

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formed by the shortest ray, and farthest from that formed by the longest ray. This condition is known as the "rule of perpendiculars," illustrated in Fig. 22.

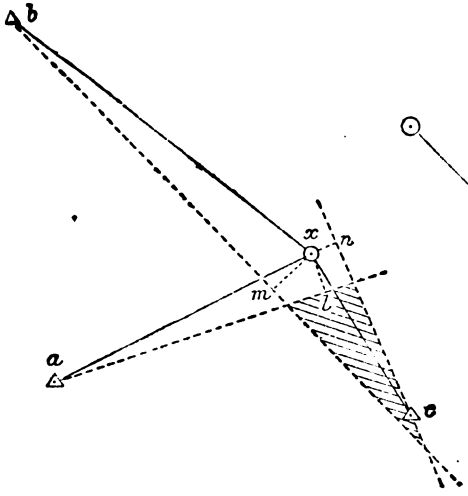

FIG. 22.

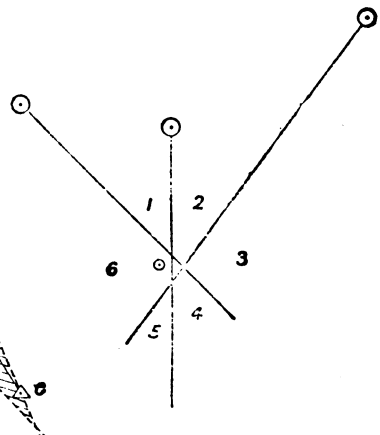

FIG. 23.

In Figs. 22 and 23, for instance :—

By condition (i) the point must be outside the triangle of error. (Figs. 22 and 23.)

By condition (ii) the point must be in sector 6 or in sector 3.

By condition (iii) the point must be in sector 6*, since the distances from it to the rays must be proportional to the lengths of the rays, and by estimation it will be where shown. (Fig. 23.)

Having thus determined the position, place the sight rule along the line joining it and the most distant of the points used ; set the sight rule on the point by revolving the plane table ; clamp and test on the other two points. If there is still a triangle of error (which, however, should be much smaller) go through the process again.

165. *Good Positions.*—The best position is commonly inside the triangle formed by the three points. If you are outside this triangle, in general the best results are obtained when the angle between the extreme rays is large : 60° is rarely more than fair whilst 180° is usually good.

Accuracy of position is ensured by two points being near ; accuracy of setting is ensured by aligning on a distant point. Generally fix from near points and set by a distant point.

* To make this clear, take a point anywhere in sector 3. It will be seen that it lies nearer to at least one of the long rays than to the shortest ray, and condition (iii) would not be fulfilled.

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166. *The Danger Circle.*—This method of resection fails when the circle which passes through the three fixed points, known as the "danger circle," also passes through your position (*see* Figs. 24 and 28). When the points and your position are exactly so related, the three rays will pass through a common point whatever be the setting of the sketch, but a different point for each setting, and it will be impossible to form a triangle of error. If you are near the danger circle you can obtain a triangle of error, but in applying the rule of perpendiculars you will find that a number of points along a certain curve appear to satisfy the conditions equally well, and an attempt at resection under these circumstances is useless.

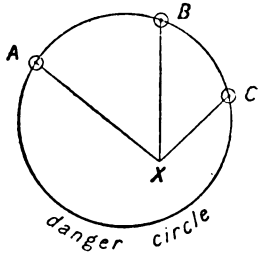

FIG. 24.

It is always possible to obtain an exact trisection, even though one or more of the three fixed points on your sketch be in error; therefore before accepting a resection it is advisable to draw a check ray to a fourth point when available.

167. *Precautions.*—The greatest difficulties attached to this method of resection are the selection of the correct sector and the application of the rule of perpendiculars. This portion of the work should be practised indoors until the necessary facility is obtained.

168. *Rule of Apices.*—Let Fig. 25 represent your first attempt at a particular resection. The angles at p, q and r are the true

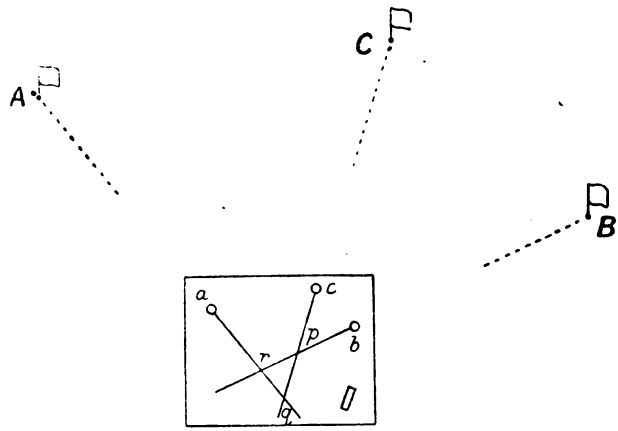

FIG. 25.

angles at your position subtended by B C, C A and A B respectively; for you have actually drawn them graphically, and these angles are quite independent of the setting of the sketch. Fig. 26

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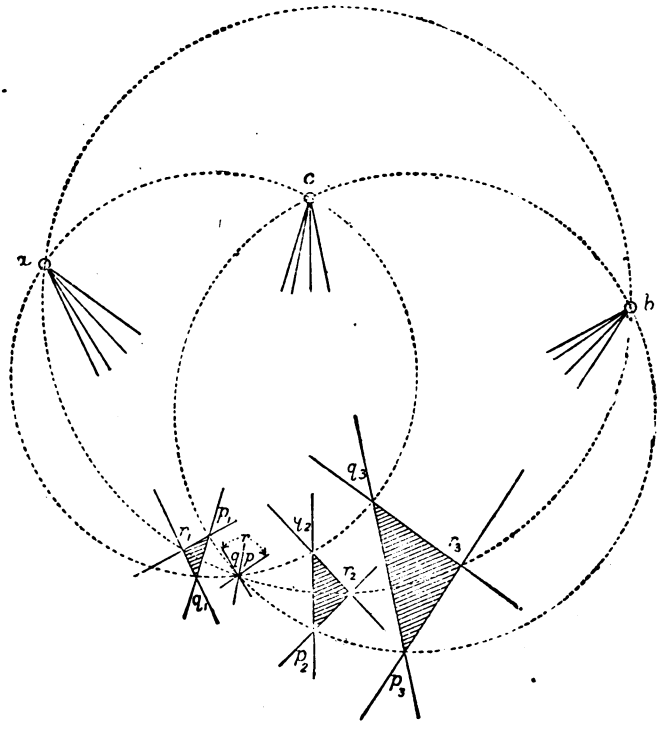
shows four attempts at a resection and therefore the angles p_1, p, p_2 and p_3 are all equal, the angles q_1, q, q_2 and q_3 are all equal, and the angles r_1, r, r_2 and r_3 are all equal. Therefore the locus of p is a circle passing through p_1, p, p_2, p_3, b and c; the locus

FIG. 26.



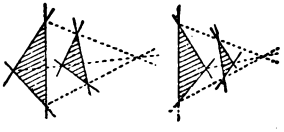


FIG. 27(*a*).

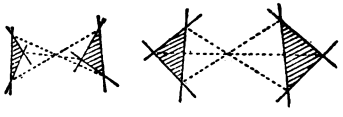


FIG. 27(*b*).

of q is a circle passing through q_1, q, q_2, q_3, c and c; and the locus of r is a circle passing through r_1, r, r_2, r_3, b and a. Your position, *i.e.*, the point where p, q and r coincide, must be the intersection of these three circles.

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Now the intersection of the three circles is approximately that of the chords $p_1 p_2$, $q_1 q_2$ and $r_1 r_2$, or of the chords $p_3 p_2$, $q_3 q_2$ and $r_3 r_2$, and the smaller the triangles of error the nearer is this assumption to the truth. Therefore, provided the triangles of error are small, the intersection of lines joining corresponding apices defines your position; this rule is known as the "rule of apices."

If the triangles of error are "in conjunction," as in Fig. 27 (*a*), the vertices are undisturbed and should be joined as shown. If the triangles of error are in opposition as in Fig. 27 (*b*), the vertices are disturbed and should be joined as shown.

169. *Failure of Method.*—In Fig. 28 let *a*, *b* and *c* be the fixed points and *x* your resected position. From the foregoing discussion it is clear that *x* must be the intersection of the two circles *a b x* and *b c x*. The danger circle *a b c* is the ultimate position of these two circles when they coincide, and in this position they may be considered to intersect at every point of their circumference, and the method then fails. Even if your position is near the danger circle, as in Fig. 28, the point of intersection of the two circles is very indefinite.

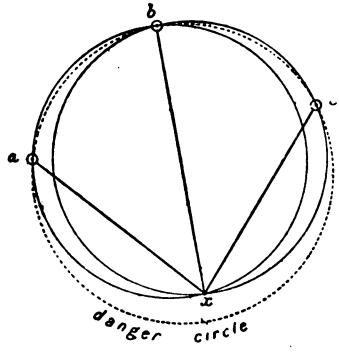

FIG. 28.

(*b*) *Resection from three fixed points with the aid of tracing paper.*

170. Pin a piece of tracing paper over your sketch and on it draw rays from any point *x* to the three points in nature.

Now move the tracing paper over your sketch until these three rays lie exactly over the three points on your sketch. Your position on the sketch now lies immediately under the point *x* on the tracing paper, and may be pricked through. Set your table and check by taking rays to various points.

This method fails if you are on the danger circle, and is very inaccurate if you are near it.

(*c*) *Resection from two fixed points by visiting two unfixed points.*

171. Let P and Q, Fig. 29, be two points in nature, the positions of which you have fixed as *p* and *q* on your sketch. Let X and Y be two other points in nature whose positions you wish to fix without visiting P or Q.

Pin a piece of tracing paper over your sketch, and on it draw a straight line *x' y'* rather longer than you expect *x y* to be on your sketch. Treating this line *x' y'* as a base and representative

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of X Y in nature, make on the tracing paper a sketch of the four points P, Q, X and Y by intersecting P and Q on the ground

FIG. 29.

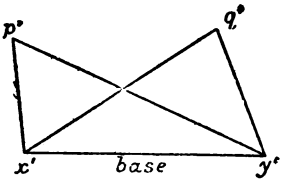

FIG. 30.

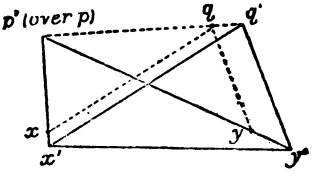

FIG. 31.

from both ends of this base X Y, quite irrespective of the work on your final sketch underneath (*vide* Fig. 30).

Now move your tracing paper over your final sketch until p' lies on p and p' q' along p q, as in Fig. 31. Pencil the position of q upon the tracing paper and draw $q\,x$ parallel to $q'\,x'$ and $q\,y$ parallel to $q'\,y'$. Prick the points x and y upon your final sketch as the positions of X and Y in nature.

In the above discussion it was tacitly assumed that the ray $x\,y$ did not cross the ray $p\,q$; however, should it do so, the method will be equally applicable provided the substitution of Figs. 32, 33 and 34 be made for Figs. 29, 30 and 31 where the latter occur in the text.

(*d*) *Resection from two fixed points with the aid of the trough compass.*

172. In Fig. 25 let R (beneath the plane table) be your position on the ground, and let A and B on the ground, represented by a and b on the sketch, be the fixed points from which you wish to resect your position. Remove the trough compass from its wooden case, place it within the compass rectangle (*v.* Art. 159), revolve the table top until the needle is steady

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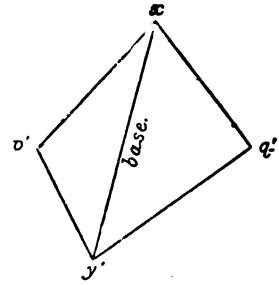
on zero, and clamp. The sketch is now set by compass. Pivoting the sight rule about *a* and *b* in turn draw back rays towards

FIG. 32.

FIG. 33.



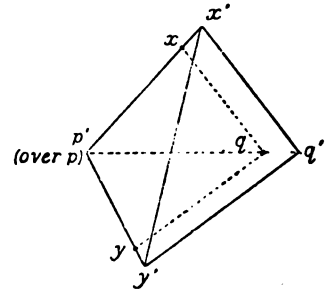


FIG. 34.

yourself from A and B in nature, and let them intersect in *r*. Now since the table is set, *a b* is parallel to A B, and you have drawn *a r* and *b r* parallel to A R and B R respectively; accordingly the triangle *a b r* is similar to the triangle A B R and therefore *r* defines your position on the sketch.

The accuracy of your fixing is dependent on the accuracy with which the sketch is set, and therefore on the reliability of the trough compass. Now the compass may be affected by local disturbing agencies or may have been so affected when the compass rectangle was originally drawn; or a combination of the two effects may have taken place. However, this method is justifiable where the resecting rays are short or where extreme accuracy is not of vital importance; but it is the least accurate method of resection, and where the rays are other than very short, it should not be adopted.

§50. Lining In.

173. This is the operation of placing your plane-table either in prolongation of the line joining two points, or directly between two points. The former is obvious; for the latter proceed as follows:

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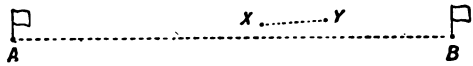
Set up the plane-table as near as can be judged on the line, (Fig. 35). Place your sight rule anywhere on the table and direct

FIG. 35.



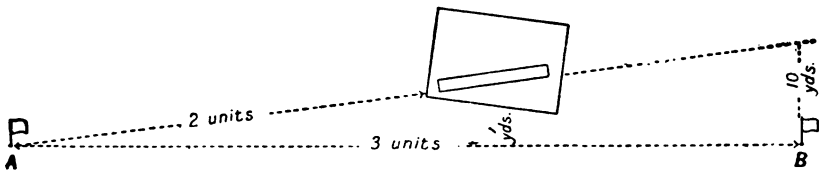


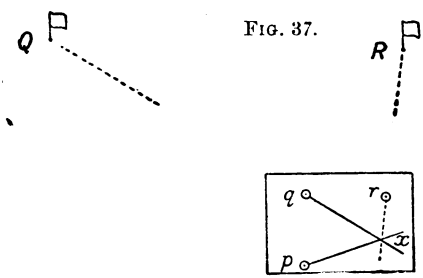
FIG. 36.

the sights upon A. Draw a line, X Y, along the edge of the sight rule. Reverse the sight rule on this line without moving the table top and look over the sights again. If the sights are on B, you are correctly placed; if to the left of B you must move to the right, and *vice versa*. Fig. 36, which explains itself, shows how the extent of your movement may be roughly estimated.

§51. Countersection.

174. In Fig. 37 let p and q on your sketch represent two points, P and Q in nature. Assume that when your sketch was set at

FIG. 37.



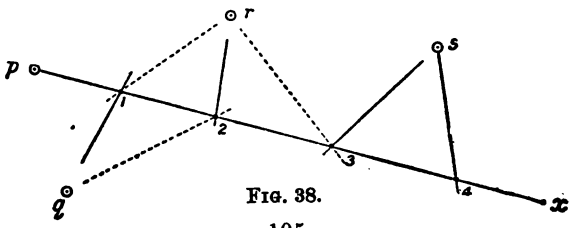


FIG. 38.

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P you drew the ray $p\,x$ towards an unfixed point X in nature. You can fix the position X on your sketch without visiting Q or any other fixed point as follows:

Proceed to X and set the sketch by aligning $x\ p$ on P. Pivoting the sight rule about q, align the sights on Q and draw a back ray towards yourself, intersecting $p\,x$ in x. This gives your position.

It will be clear that not only the point X, but any point in the line P X either between P and X or beyond X, supposed marked, might be plotted in a similar manner by first lining in, then setting the sketch by aligning the ray $x\,p$ on P or X, and proceeding as described above. This method of fixing a position is known as "countersection." It is evidently a form of resection in which you are aided by the ray previously drawn. The position and setting should always be checked by a ray to a third point.

Fig. 38 exemplifies a number of countersections, 1, 2, 3 and 4 on the ray $p\,x$. This procedure is known as "driving a line."

§52. Traversing with the Plane Table.

175. *Application and Restriction.*—This method of sketching is generally applicable to an area which has considerable length and not much breadth. It is a method of executing a sketch of a road, railway, river or coast reconnaissance, or the reconnaissance of an outpost position. Occasionally it may even be necessary to apply this method as the sole means of sketching an area in which the flatness or closeness of the country precludes the use of any more accurate method, which in many cases might be too slow. A special method of adapting short traverses to otherwise accurate work is discussed in Art. 180.

Traversing is opposed to the general principles of British plane-tabling, which relies on independent fixings and avoidance of accumulated errors, and should never be employed except when absolutely necessary.

176. *Procedure.*—Suppose it is required to sketch the course of a stream with adjoining detail, a portion of which is repre-

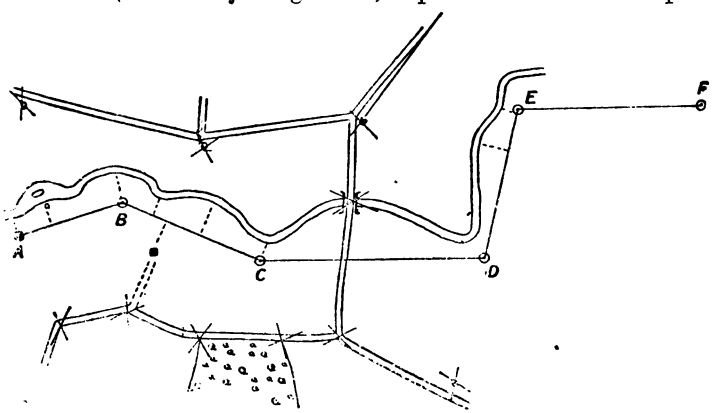

FIG. 39.

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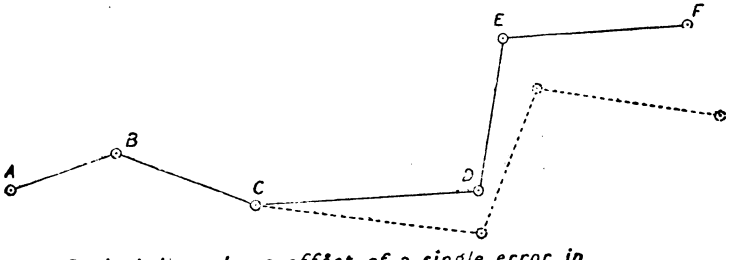
sented in Fig. 39. Let A, B, C, D, E and F be recognizable points near the stream, each of which is visible from the next preceding and following points.

Choose a point on your sketch to represent A in nature, and draw a straight line *a b* to represent the direction A B.

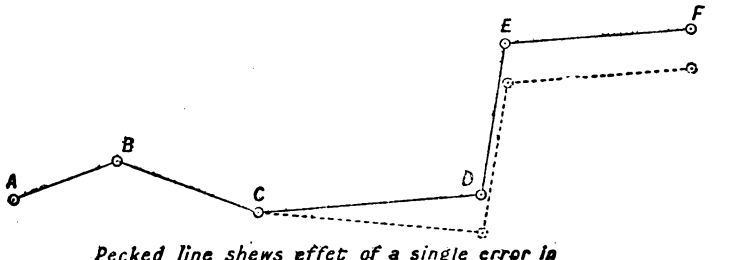
Pace the distance A B and mark a point *b* on *a b* such that *a b* represents the paced distance A B to scale. At B set the sketch by laying the edge of the sight rule along *b a* and rotating the table until the sights are directed upon A in nature. This method of setting the sketch is known as "setting by the back ray." With the table clamped, pivot the sight rule about *b* until the sights are directed upon C and draw the ray *b c*. Pace the distance B C and plot *c* to scale on your sketch. Proceeding in this manner the skeleton of a traverse is obtained, each of the portions A B, B C, &c., being called "legs."

Detail may be inserted on the sketch by eye, by intersections or by "offsets." An offset is the distance of a point from the leg of a traverse, measured in a direction perpendicular to the leg. This distance may be paced or estimated. It will also be necessary in the process of pacing the leg to note the distances

FIG. 40(*a*).



Pecked line shews effect of a single error in setting by back ray at C.



Pecked line shews effet of a single error in setting by compass at C.

FIG. 40(*b*).

at which the offsets occur. Data for plotting offsets should be noted on a piece of paper and the offsets should be plotted on

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reaching the end of the leg. The offsets necessary to plot the position of the stream in Fig. 39 are shown in dotted lines and typical intersections are also indicated. It may occasionally be desirable to draw a ray to some point of detail from an intermediate point in a leg, in which case it will be necessary to "line in" carefully before setting the sketch.

177. *Setting by the Back Ray.*—The method of setting the sketch in traversing by means of the back ray has great disadvantages.

Suppose that when you were at C you mistook your last station B and set your sketch incorrectly. This one case of bad orientation will have a cumulative effect on your subsequent work, even though you make no further mistakes. Fig. 40 (*a*) exemplifies this, the firm lines representing the true positions of the legs and the pecked lines the erroneous positions.

What we have called a "back ray" must be drawn originally as a forward ray, and therefore, unless you are prepared to walk over each leg three times you must choose your forward station without knowing for certain that a good forward view is obtainable from it. On this account, it will often be found necessary to include a short leg, such as Q R in Fig. 41, in order to obtain a satisfactory forward view.

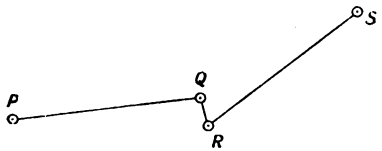

FIG. 41.

178. *Setting by the Trough Compass.*—Instead of setting the sketch by the back ray, the trough compass may be used, and this method is probably the better of the two. The procedure would then be as follows:

Set up your table at A, Fig. 39, draw any rays which you may require for intersections, and also draw a "compass rectangle." Now pace forward in what you consider will be the direction of your first leg. If on your arrival at B you do not like the position of this point, you may move to a more convenient position, making due allowance for the change, if any, in the length of the leg.

Set your sketch by means of the compass. Pivot your sight-rule about *a* until the sights are directed on A in nature, draw the back ray *a b* towards yourself and plot the leg *a b* to scale. It will be seen that the final decision regarding the exact position of the forward end of a leg need not be made until the point is actually reached, and the necessity for an occasional short leg, as shown in Fig. 41, is obviated. However, if offsets to detail are to be made, a forward ray must be drawn for that special purpose; but your forward point need not necessarily lie on that ray. If you make a mistake in orientation at one point and the subsequent work be correct, the effect on your traverse as a whole will be considerably less than in the case

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of one bad orientation when the method of setting by the back ray is adopted. Contrast Figs. 40 (*a*) and 40 (*b*).

179. *Control of Traverse.*—In a survey of a long belt of country by traversing, there will usually be no means of checking the work, unless the traverse starts from a previously fixed point

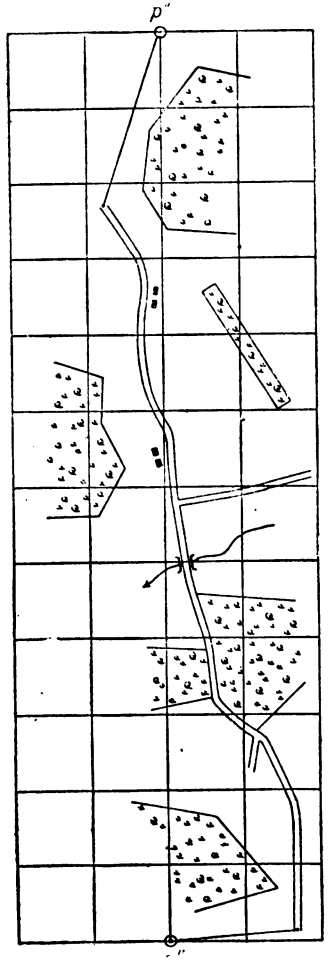

FIG. 42(*a*).

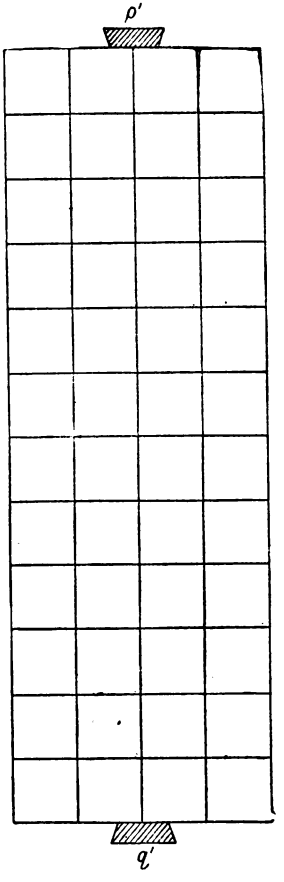

FIG. 42(*b*).

and closes on another, in which case the work should be adjusted as described in Art. 180.

When the area is not a narrow belt, and yet traversing is the only reasonable means of survey, a control traverse should be run near the edge of the area, starting and finishing at the

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same point; any error of closure is adjusted by moving each point in proportion to its total distance along the traverse from the starting point.

Subsidiary traverses should then be run across the area, starting and closing on points of the control traverse and adjusted as described in the preceding paragraph.

180. *Subsidiary Traverses.*—In the course of surveying an area by the more approved methods, it is often impossible, owing to locally restricted view, to sketch certain limited portions except by resorting to traversing.

In this case it is often useful to work the traverse on a sheet of paper, Fig. 42 (*a*), other than that of the sketch proper, and afterwards transfer to the map by reducing to the required scale by squares, as in Fig. 42(*b*). The traverse must start and finish on previously fixed points, such as p' and q'.

§53. Methods of Sketching Detail.

181. *General Procedure.*—So far we have considered the various methods of fixing points. Such points may in themselves be points of detail, such as buildings, isolated trees, road or hedge junctions, corners of woods, &c., or generally any prominent object of small dimensions.

Detail is sketched in by eye, controlled by instrumentally fixed points. The number of these points depends on the time available, the accuracy required and the nature of the detail to be fixed. Detail must be straight or crooked. If straight two points will fix it, or one point and a ray. If crooked, a number of points and direction rays must be fixed. As the graphic triangulation proceeds the sketcher will draw rays from each occupied point, not only to new control points, but also to such points of detail as he thinks will be required.

Do not, however, attempt to draw a great number of such rays from any one point: only confusion will result. It is far better to draw only a few rays to really conspicuous and easily recognizable points. Remember that you will probably have to pass over most of the ground, and that you can then resect your position on the actual site of most of the required points.

182. *Example of Sketch.*—Plate XIX shows in red, blue and green, the successive stages in the work of a plane-table sketch, from the beginning. The portion shown in black merely represents the remaining area of ground included in the sketch. No attention need be paid as yet to the form-lines. If you wished to fix instrumentally more points than are shown in the plate, you would probably do so by resection, and possibly occasionally by countersection.

183. *Provisional Indications.*—When you draw a first ray to a point, estimate the distance of the object and mark its estimated position lightly on the ray. Possibly you may never get

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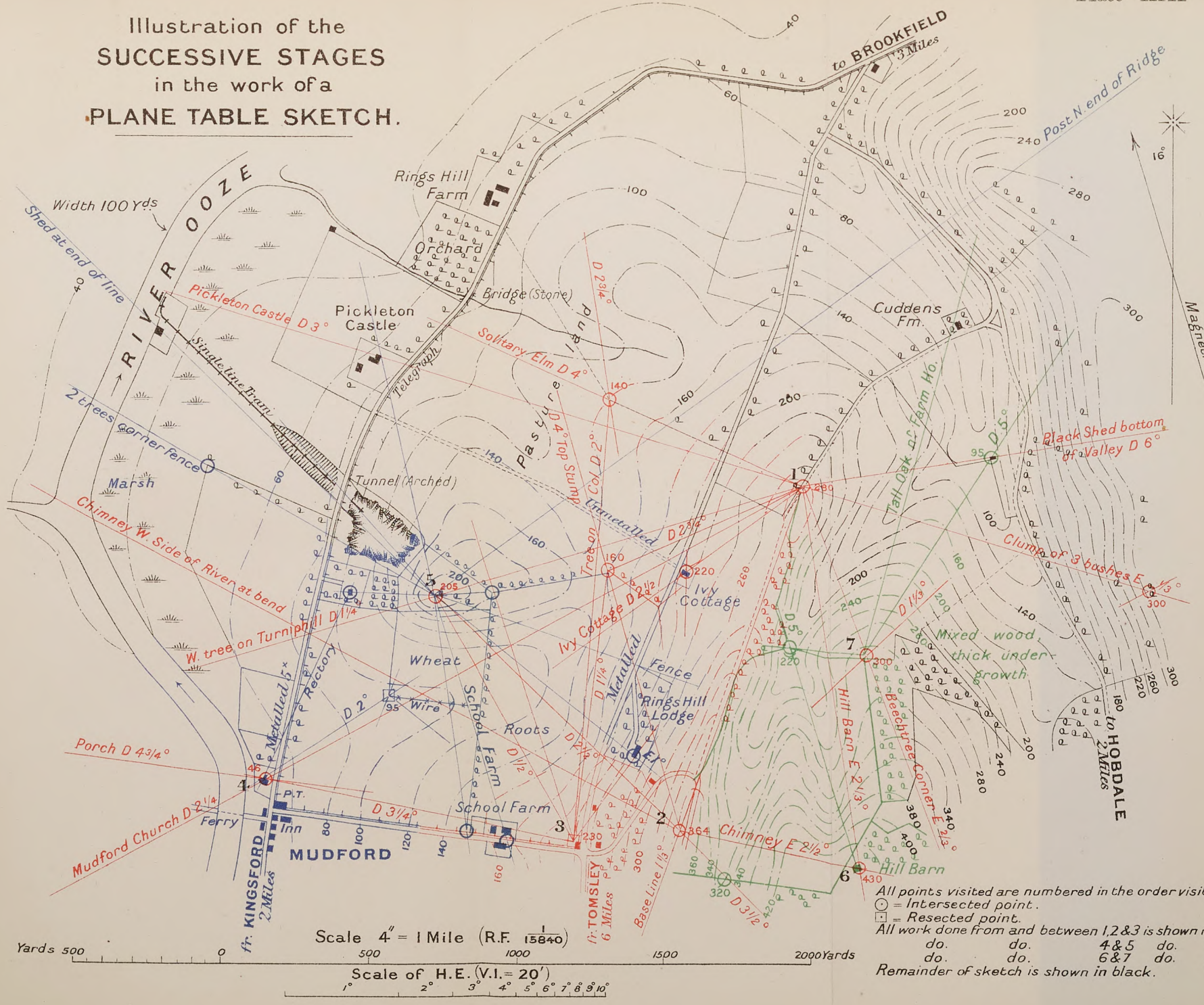
Illustration of the SUCCESSIVE STAGES in the work of a PLANE TABLE SKETCH.



All points visited are numbered in the order visited.
⊙ = Intersected point.
⊡ = Resected point.
All work done from and between 1, 2 & 3 is shown in red.
do. do. 4 & 5 do. blue.
do. do. 6 & 7 do. green.
Remainder of sketch is shown in black.

Scale 4" = 1 Mile (R.F. 1/15840)

Yards 500 0 500 1000 1500 2000 Yards

Scale of H.E. (V.I. = 20')

1° 2° 3° 4° 5° 6° 7° 8° 9° 10°

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another ray to this point and you may have to accept the estimated position, which will in any case be useful for identification. Do not draw the whole length of the ray, but only so much as is necessary to be sure of passing through the point. All short rays should have their extensions marked on the edge of the sketch if they are to be used later for setting the sketch. When it is desired to sketch a complicated network of hedges or similar detail from two stations, not only should the estimated positions of the points sighted be marked on the rays drawn from the first station, but the hedges themselves should be indicated (*vide* Fig. 43) as a guide to identification from the second station.

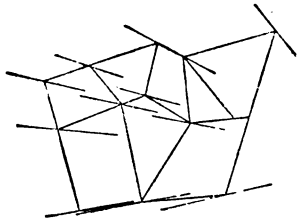

FIG. 13.

184. *Change of Position.*—Situations will frequently occur in which you cannot resect at a desirable point Y but can resect close by at a point X. You may then resect at X and fix Y by ray and paced distance, provided that the distance is such that the probable error in pacing it is not plotable at the scale of your sketch. Having thus fixed Y, you should set your sketch at this point by means of a long ray and not by the very short ray Y X. This method enables you generally to change your position

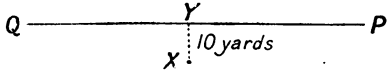

FIG. 44(*a*).

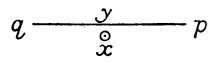

FIG. 44(*b*).

slightly from one that is good for resection to one that is good for viewing detail. It allows you to move to the other side of a hedge, wall or other obstruction, over the brow of a hill, &c.

Occasionally a slight change of position is required only in order that you may place yourself actually on, or in prolongation of a straight piece of detail, for the purpose of drawing a ray along it. Provided the two points are not farther apart than 20 yards, the ray can be drawn as follows, without actually moving the table from the resection point.

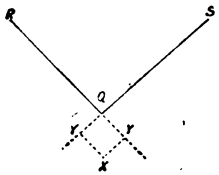

FIG. 45.

In Fig. 44 (*a*) let X be your resection point and P Q a straight hedge whose direction you wish to sketch. Pace the perpendicular distance X Y to the hedge, in this case 10 yards, and plot this distance along the ray *x y* on your sketch, as in Fig. 44 (*b*). With your sketch still correctly set at X, pivot your sight rule about *y*, direct the sights on any distant point judged to be 10 yards clear of the hedge and on

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your side of it, and draw the ray *p y q* to represent P Y Q. It is not necessary that the detail should actually pass your resected position, provided the distance X Y is short and you measure it perpendicular to the detail. For instance, in Fig. 45 the detail Q R and Q S could be sketched without moving the table from X.

185. *Exaggeration of Curves.*—There is generally a tendency to exaggerate the departure of a curved line from the straight, when you are viewing the curved line more or less in the direction of

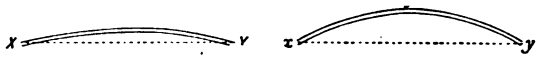

FIG. 46 (*a*). FIG. 46(*b*).

its length. A road X Y, Fig. 46 (*a*), when sketched from X, is often represented on a sketch as shown in Fig. 46 (*b*). The correct procedure is to estimate how far the detail departs from the straight and to sketch it conformably.

186. *Usefulness of Resection.*—It will be found that resection assumes a most important part in the fixing of detail. Resection from three points is just as accurate as intersection from two points, and resection generally has the following advantages over intersection :—

(i) You fix the position of your actual standpoint whilst you are on the spot, and this standpoint need not be marked by any object or feature in nature.

(ii) When you are working from trigonometrically fixed points which you have plotted by their co-ordinates, you will often find these inaccessible, such as church spires, and resection is the only method available.

Actual points of detail are generally fixed by intersecting rays drawn from resected points. As the sides of ridges and spurs are generally convex and are therefore invisible from the back of the ridge or spur, it will often be found convenient to sketch the detail on the sides of one ridge by rays drawn from two or more resected points on an adjacent ridge. Methods of sketching the detail of watercourses are discussed in Art. 191.

187. *Combination of Processes in Practice.*—Although the main graphic triangulation, the " breaking down " and the sketching of detail, have been discussed separately, these three operations may, in fact, be performed simultaneously. As soon as you have fixed two points of your main triangulation, you can employ intersection or countersection in order to " break down " or fill in detail ; as soon as you have three main points you can start resection for the same purposes. An accomplished sketcher will be able to effect this procedure, and will completely build his sketch as he moves over the ground ; but he will differentiate

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carefully between the three processes and will observe a proper sense of values. The beginner should separate the processes in his first sketch, should combine them in a very limited sense in his second, and so on, always aiming at complete combination and consequent saving of time.

§54. Methods of Sketching Relief.

(*a*) *Contouring or form-lining.*

188. Form-lines have been defined as approximate contours. The same principles hold whether the topographer is surveying contours or sketching form-lines: the following description applies to both. The word "form-lining" will be used throughout, for it is but seldom that a soldier has time to survey contours.

Chapters V and VI deal with the methods of reading the relief of a tract of country from the contours or form-lines depicted on a map or sketch. We are here concerned with the reverse process of reading the relief from nature and depicting it on a sketch by form-lines. Many of the lessons to be drawn from Chapters V and VI and Appendix III are applicable to both processes.

Now a sketch with form-lines tells you directly that the height of every point on a definite form-line has a particular value, but indirectly it tells you many things regarding the relief of the country:—

(i) The trace of watercourses.

(ii) The traces of ridges and spurs, and whether they are blunt or sharp.

(iii) The positions and shapes of cols, knolls and peaks.

(iv) The lines on which uniform slopes change their gradients.

(v) The character of a slope: whether uniform, concave or convex.

(vi) Where the ground is flat and where broken.

189. *Delineation of Form.*—The black portion of Plate XX shows the information, both direct and indirect, given by the sketch on Plate XXI. Treating the black portion of Plate XX as a skeleton, let us reconstruct the form-lines without the aid of Plate XXI.

The crossing points of form-lines on ridges, spurs and watercourses should be marked first, and then the form-lines themselves should be drawn conformably; and in both processes due attention should be paid to the lessons drawn from Appendix III.

The treatment should be effected in the following order:— Main ridges and watercourses, minor ridges and watercourses, spurs and other slopes and tributaries.

Consider the main watercourse, and guided by the two heights 610 near its source, and 446 further down, interpolate by trial

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and error the probable crossing points of form-lines. Bear in mind that watercourses are generally concave, and therefore, the form-lines would normally be fairly close together near the source and gradually separate as the watercourse is descended.

Now, following the main ridge downwards, mark the 620 form-line just above the point 619. The 600 form-line must occur between points 619 and 591. The drop from 619 to 591 is 28 feet; the drop from 619 to 600 form-line is 19 feet; therefore, the drop to the form-line is 19/28 or, roughly, two-thirds of the total drop. Therefore, mark the form-line by eye two-thirds of the distance along the line 619 to 591.

The 600 form-line will occur again between points 591 and 613, but as 613 is marked as a knoll and therefore probably has steep sides in the region of the knoll itself, it will suffice to mark the 600 form-line as a small ring round this point. Let *c* be the point where this ring form-line cuts the next ridge line.

Between *c* and point 546 the slope is uniform and is crossed by two form-lines, 580 and 560, at points *e* and *d*. Point *d* can be found by either of the methods described above, and *e* will occur half-way between *c* and *d*.

The spur from point 546 to point 469 is uniform. If we mark the crossing points *f* and *g* of the 540 and 460 form-lines, we can space the intervening form-lines uniformly.

With regard to the convex slope between points 546 and 461; mark the 460 form-line immediately below point 461 and space the form-lines as shown at *h* by trial and error, so that they may define a convex slope.

190. *Completing the Representation.*—All the other ridges and spurs should be treated in a similar manner, but in most cases it will first be necessary to interpolate heights for the tops and bottoms of the slopes. For instance, the height of point *x* may be taken as 485 feet, and the height of point *y* as 565 feet. Where the slopes are not uniform we can only show them approximately, since the data given to us do not state the degree of convexity or concavity.

The remaining watercourses should be treated in exactly the same manner as the spurs, but in default of definite information, we must assume that they are concave and mark the crossing points accordingly.

When all the crossing points of form-lines have been marked, the form-lines themselves should be drawn. Guided by the interpolated heights and the rough descriptions of the features, first lightly draw every fifth form-line; then lightly draw the form-lines which occur midway between these, and so on. Finally, go over the work more firmly, correcting where it is considered that the features are not reasonably represented.

From the above discussion it will be seen that the information given on Plate XX is sufficient to enable the relief to be shown by form-lines in an office without having previously seen the finished sketch or the actual ground represented. In fact, it

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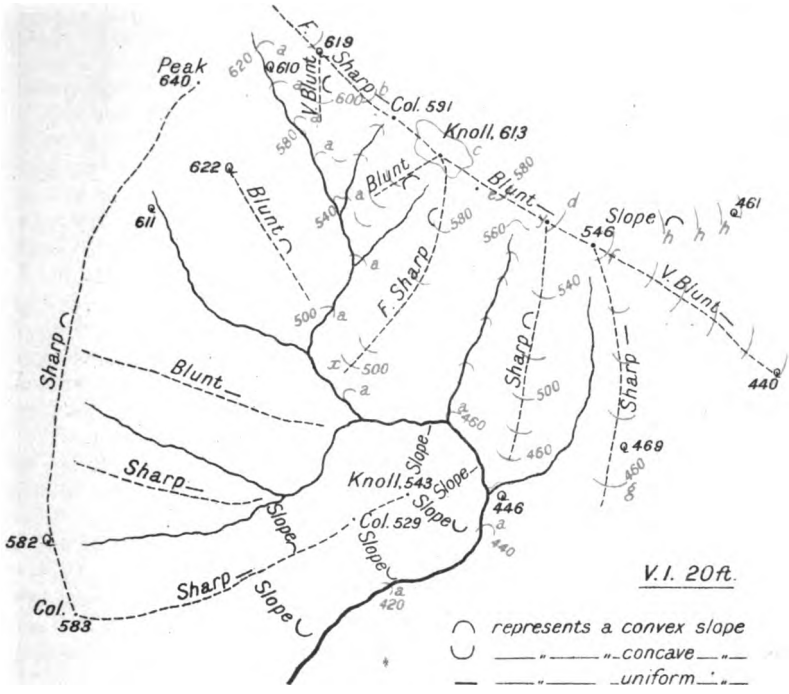
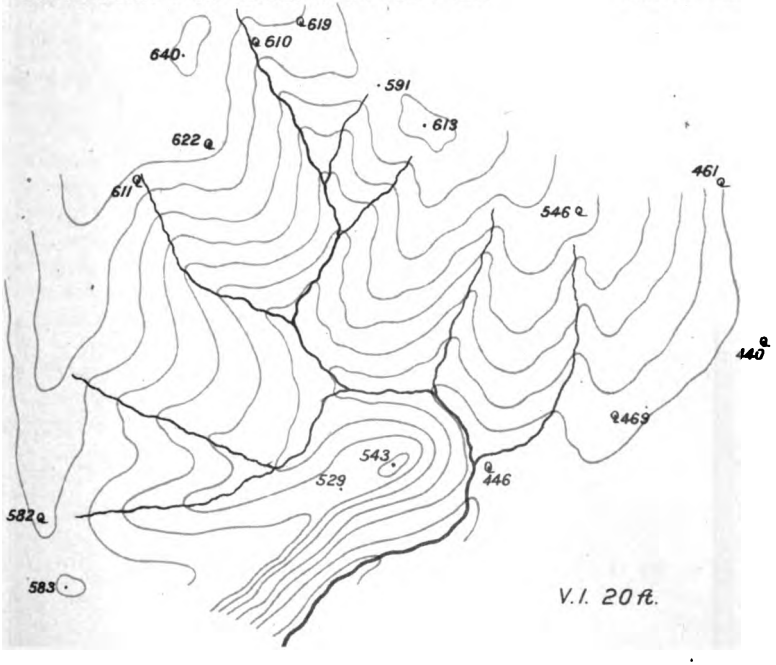
Material for making a Sketch of Relief. Plate XX



Sketch shewing Relief
constructed from material on Plate XX. Plate XXI



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may often transpire that, owing to hostile activity, the sketcher cannot remain sufficently long in the field to complete the form-lining *in situ*.

The method of sketching the information required in Plate XX in no way differs from that of sketching any other detail. The backs of ridges and spurs being somewhat indefinite as a rule, points on them would be resected, or they would be sketched by eye in relation to other detail points which are more readily fixed.

191. *Watercourses.*—The sketching of watercourses merits some particular attention. If the bed of a watercourse is generally visible from the surrounding country, no difficulty should be experienced; but if it is shut in by steep or convex banks, a certain amount of ingenuity is required. The directions of the various reaches may possibly be fixed from high ground in prolongation.

The tops of trees or buildings near the banks may be capable of intersection from higher ground though their bases may be out of sight. If from the bed of the watercourse an occasional view of a fixed point is obtainable, a line may possibly be "driven" down it.

From the fixed points on the high ground on one side of the watercourse, a couple of points low down on the far slope may be visible and capable of being fixed, and from these latter two points it may be possible to intersect points on the watercourse itself.

192. *Additional Remarks.*—In the representation of a very gently sloping valley, plain or plateau, possessing very vague features, a single contour line, though accurately surveyed, would convey very little more information to a map-reader than would a boldly drawn form-line. Therefore, in such cases be bold in drawing your form-line. It is in this type of country that a beginner chiefly suffers from bewilderment.

When sketching the relief at any station, do not attempt to make the local form-lines show every little minor feature in your vicinity. You cannot show such detail everywhere; therefore show it nowhere.

The actual amount of detail which can be shown depends on the scale of your sketch.

On the other hand, you should "rough in" as much form-lining as possible from each station, provided that such form-lining has any pretentions to accuracy; but the drawing should be effected neatly and in some specially distinctive manner. Although you do not necessarily expect all this work will stand good, certain benefits will follow:—

(i) You will gain experience in sketching what you see without depending too much on guiding heights.

(ii) What you depict on the sketch is a description of what you see, and this view may never be repeated. The presence of a small but important feature might be overlooked if not evident from another view-point.

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(iii) You help to link up portions of accurate work and give a realistic effect or tone to the general sketching of the relief.

The sketching of the relief should progress simultaneously with that of the detail. The beginner will have a distinct aversion to this procedure. His natural inclination will be to sketch the detail first, and then go over the ground again and sketch the relief.

Undoubtedly, this should be the practice in the very early stages of tuition or self-tuition; but bear in mind that it is wasteful of time, and that as soon as you know how to carry out the two processes you should practise them in combination.

(b) Method of Obtaining Heights by Clinometer or Level.

193. Although we have decided that the heights of a number of ruling points are essential, we have not yet discussed the manner in which these should be obtained.

It is common knowledge that if one climbs a uniform slope, the amount of rise is proportional to the distance travelled. If one rises 100 feet in half a mile, one would naturally rise 200 feet in a mile. Turn to Fig. 47. It is a fact that on a slope of 1° you will rise 1 foot in approximately 20 yards (more exactly 19·1 yards), and therefore you will rise H feet in $20 \times H$ yards. This is the same thing as if we were to say that your rise is $H/20$ feet in H yards of a 1° slope.

Now on a 2° slope you rise approximately twice this amount in the same distance. That is to say, your rise in H yards of a 2° slope is $2\ H/20$ feet.

Generally then, your rise in H yards of a $D°$ slope is $D.\ H/20$ feet. If the difference of level in this length of H yards is V feet, we have therefore

$$V = D.\ H/20.$$

This is the general formula connecting the horizontal distance H in *yards*, the vertical distance V in *feet*, and the slope D in *degrees*, and is sufficiently accurate for sketching purposes provided the slope is not greater than 8°. Since V is the quantity you generally wish to obtain, H and D being known, the formula should be committed to memory in the following form:

$$V = D \times \frac{H}{20.}$$

If V and H are required in the same measure, say both in metres, the denominator of the fraction should be changed from 20 to 60 (more accurately, 57·3).

194. *Application of Formula to Distant Point.*—Now if you have fixed on your sketch the positions of two mutually visible

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points, you can measure the horizontal distance between them from your sketch, *i.e.*, *H*. If, further, at either of the points you

FIG. 48.

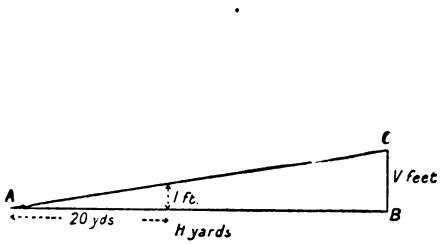

FIG. 47.

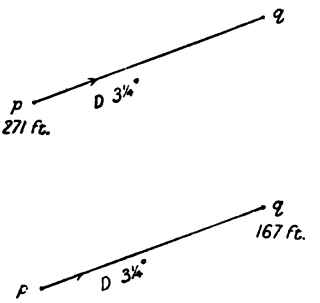

FIG. 49.

observe the degree of slope to the other, you have *D*, and the formula gives you the difference in height between the points irrespective of whether the angle is an elevation or a depression. If the angle is an elevation, the distant point is above you, and *vice versa*. If you know the height of one of the points, you can at once deduce the height of the other by applying the difference in height as a positive or negative correction.

Let Fig. 48 represent a portion of your sketch, *p* and *q* being two fixed points representing two points P and Q in nature, and assume that you are stationed at P. Suppose the height of P be 271 feet and that you wish to find the height of Q. Measure the angle of slope to Q, and let it be a depression of $3\frac{1}{4}°$. Measure the distance *p q* from the sketch, and let it be 643 yards. Then

by the formula $V = D \frac{H}{20}$ we have

$$V = 3\tfrac{1}{4} \times \frac{643}{20} = 104 \text{ feet.}$$

Since the angle of slope is depression, Q is lower than P, and its height is, therefore, 271 − 104 or 167 feet. This method of fixing the height of a point at which you do not stand, is known as "throwing a height to a distant point."

195. *Application of Formula to Standpoint.*—Now, if instead of knowing the height of the point P at which you stand, you know the height of the distant point Q to be 167 feet (*vide* Fig. 49), you may have to find the height of the point P at which you stand. The difference of height between the points remains unchanged, since none of the quantities have changed, and since you are above Q, your height will be 167 + 104 or 271 feet. This method of fixing the height of a point on which you stand is known as "taking a height from a distant point," and is the method

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employed in fixing the height of a resected or countersected point.

Allowance should always be made for the height of the instrument above the ground at the point of observation.

196. *Number of Heights.*—The form-lining of Plate XX would be much easier were there more fixed heights scattered over the area. As a general rule you should fix the height of any point the position of which you have fixed in plan, unless the height of a point would be obviously of no use to you. Before considering that the height of a point has been fixed definitely, values of its height should be obtained from at least two points as a check against error. It therefore follows that practically every ray you draw for the purpose of fixing the position of a point in plan by intersection, should have the slope of the ray marked against it. This has not been done in the sketch shown on Plate XIX in order that the work may be more legible.

Frequently it is important to fix points simply in order that you may "height" them as an aid to form-lining.

197. *Choice of Points for Height.*—In resection or countersection it is not essential that you should take your height from the points utilized in fixing your plan position: your height may be taken from any previously fixed point.

As resection and countersection are largely employed in the fixing of detail, it is a great convenience if you can select some distinct and conspicuous point from which to take your heights in each restricted area of the ground to be sketched, and this procedure tends to greater relative local accuracy. In such cases check heights should also be taken from other points; but these should be treated only as guards against gross errors, your accepted height being that obtained from the specially selected point.

Do not accept a height resulting from a long ray, nor incorporate it in a mean.

You will always have at least two values for your height. If one is obtained from a short ray and another from a long ray, treat the height obtained from the long ray as corroborative only. The reason for this is that the result of an inaccuracy in reading a slope is accentuated if the ray be long. As an example, assume that slopes are read as 2° to each of two points, distant 500 yards and 5,000 yards, each slope being read ¼° too great. If the height of your position be zero, the true heights of the distant points will be 44 feet and 438 feet, whereas the heights calculated from your faulty readings are 50 feet and 500 feet; the height of the nearer point thus being 6 feet in error and the height of the distant point 62 feet in error.

198. *Datum.*—If no general datum height is obtainable in the area to be sketched, assume a height for the first point of your sketch, and the resulting form-lines will be relatively correct. If the height of a general datum point is available, but this point does not happen to be the first point of your sketch, you should

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include the datum point in your graphic triangulation and carry the height back to the base by the quickest route.

As it is possible that your sketch may be joined to other sketches to form a mosaic, you should make a marginal note regarding the accepted datum height.

199. *Spot Heights.*—Spot heights on a finished sketch are often of very great importance, since they are naturally more accurate than interpolations between form-lines; but they should only be shown where the exact points are actually recognizable on the ground from the information given on the sketch.

200. *Special Artifices.*—The following procedure is often very useful: Suppose that at any fixed station you set your clinometer at zero and note what conspicuous points are on the same level as yourself. Draw rays to these points and mark their estimated positions (for identification later) on these rays together with their height, *i.e.*, the height of your own position. When you set up elsewhere, occasions will often arise when you may save yourself trouble by again setting your instrument at zero and estimating how far a level ray passes above or below one of these points.

Very often when the ground slopes uniformly away from you, and you have no fixed points from which to interpolate the form-lines, it is a convenience to "step" for form-lines as follows. Read the degree of slope, and then by means of the formula $V = D\frac{H}{20}$ calculate the horizontal distance, generally known as the "horizontal equivalent," or H.E., between successive form-lines. If V, here the V.I., be 20 feet and the degree of slope be $5\frac{1}{4}°$, we have $20 = 5\frac{1}{4} \times \frac{H}{20}$; whence H, here the H.E. = 76 yards. If your position is not exactly on a form-line, you should first calculate where the next form-line will occur above or below you. Suppose you are dealing with ground sloping away from you, down-hill, and that your height is 252 ft. The next form-line below you will be 240 feet, *i.e.*, 12 feet below you vertically. We have then

$$12 = 5\tfrac{1}{4} \times \frac{H}{20};$$

whence $H = 46$ yards.

Therefore first step off 46 yards to the 240 form-line, and space successive form-lines at 76 yards until you judge that you have reached the foot of the slope. In reading the degree of slope for the above purpose, bear in mind that your instrument is a certain height above the ground on which you stand, and your line of sight should therefore pass a similar height above the ground at the other end of the slope.

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(c) *Method of Obtaining Heights by Aneroid Barometer.*

201. It will be noted that all the methods of form-lining described in this chapter are dependent on eye-sketching between points the heights of which you know. The method of discovering the heights of the points is immaterial provided you obtain the degree of accuracy required. The aneroid barometer will give you differences in height, and may therefore be used for this purpose, but the resulting work may only be considered as very approximate. If the height scale be set correctly, the reading of this scale will give you an approximate value of the height of any point visited subsequently, but it will be necessary to visit every point whose height is required.

Now although the reading of a barometer changes with the weather, it is found that it has also a constant wave-like change throughout the day. In the course of sketching, the time spent stationary at a point is always far in excess of the time spent in moving from point to point on the average. Suppose we cut out the eccentricities of the barometer when at rest at a point, thus :—When you have finished work at your first station set the barometer to agree with your height. Move to your second station, allow the barometer about five minutes in which to become steady, then take the reading and record it on your sketch. When you are about to leave this second station, look at your barometer and if it has changed its reading, reset it agreeably with your height before moving off, and continue this procedure at every point visited.

The aneroid barometer is generally used in sketching the relief of a traverse.

§55. Concluding Remarks.

202. The following general "tips" may prove useful to the beginner.

In the progress of your work, keep your sketch as neat and clean as possible: neatness tends to accuracy. When carrying the plane-table top in its cover on your back, see that the sketch is turned away from your back.

Use a sharp pencil, particularly for "ray" work. A pencil should be sharpened with a sharp penknife, and the point should be whittled down to a long symmetrical cone. The point should be touched up finally by rubbing it on smooth paper until it feels like a needle point when applied to the finger, and this touching up should be repeated at frequent intervals. Use a point protector.

You cannot perform accurate work with a sight rule that has a crooked edge. The best test is to rule a line against the edge, then reverse the sight rule and rule another line with the same edge. If the ruled lines appear as shown in Fig. 50 (*a*) or 50 (*b*) the sight rule is useless.

A drawn ray which purports to pass through a point on your sketch, should in truth pass through that point if produced.

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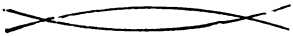
Therefore, before drawing such a ray, test your pencil against the point in order that you may know at what angle the pencil should be held in relation to the guiding edge.

A ray which is destined to remain on the sketch for some time should be only sufficiently heavy for the purpose, whilst a ray for resection, which is only required to last for a few minutes, should be so light that you can only just see it.

FIG. 50(*a*).



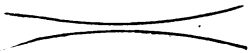


FIG. 50(*b*).

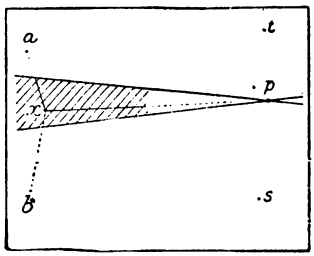


FIG. 51.

When attempting to direct the sight-rule upon a distant or indistinct point, keep both eyes open and you will find that you can see the point more clearly than with one eye only. If this does not suffice, by means of your field glasses pick up a nearer point in the true alignment and align your sight rule on this auxiliary point.

When drawing a ray which will be used subsequently for setting the sketch, as in traversing or countersection, draw also a tick at both ends of the ruling edge of the sight-rule, so that you may replace the sight-rule on the ray with greater accuracy when it is required to do so.

Always endeavour to keep yourself in good humour with your work. If you find yourself in difficulties in a certain region, owing to accumulated error, lack of fixed points or any other reason, change your ground radically and work towards that region from a new direction.

203. Although it has been laid down as a maxim that rays which fix a point should intersect bluntly, a point fixed by an acute intersection may prove of considerable value for resection, and for this purpose only, provided it be used judiciously. In Fig. 51 above, *p* may be used for resection provided you are within the shaded area or even slightly outside it, but should not be used when in the region of *s* or *t* or of the point itself. Thus the point *x* may be fixed by resection off *a*, *b* and *p*, *x p* being the long ray.

In resection always test on a fourth point; otherwise make absolutely certain that you are not on the danger circle. Remember that your fourth point may be on the danger circle also, in which case it will be useless.

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If you are actually on the danger circle, your three rays will pass through a point for any setting of the sketch, and without a test you may consider that you have "fluked" a correct setting and proceed to draw rays to detail: confusion will result. The compass in this case gives a useful check, but not a perfect control.

Before proceeding to test a resected point, as a preliminary measure delete the existing rays. In order that your selected point shall not disappear as well as the rays, place your pencil vertically on the point, and without exerting more pressure than that afforded by the weight of the pencil, twist the pencil half a revolution. You will find that a certain amount of graphite becomes ingrained in the paper and will not be removable by light rubbing. When you have finally tested and approved of your point, and not till then, prick it.

204. Every fixed point on your sketch should be pricked. A round-headed steel pin or a needle with a piece of sealing wax on the blunt end, acts well as a pricker. You should carry several of these. A pricked point is never lost, it is a nice point to work to, and can be cleaned.

A sheet of newspaper stuck in a hedge is visible from a great distance.

The form-lining of considerable wooded areas in a sketch often presents difficulty. As a preliminary measure, always work your form-lines to the boundary of the wood from the outside. If the general relief of the wooded area is visible from outside vantage points, sketch the form-lines from these points by eye, guided by a few heights thrown to conspicuous trees. If the relief of the wooded area is not visible from outside, you should run one or two traverses along paths, heighting all your stations, and then sweep in the form-lines conformably to the best of your ability.

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Chapter XV.

SKETCHING WITH THE PRISMATIC COMPASS.

§56. Plotting and Reading Bearings with the Service Protractor.

205. The preliminary remarks contained in Chapter XIV, §§47–8, are equally applicable to Prismatic Compass sketching and to plane-tabling. No elaborate table or sketching case is required to carry the sketching paper: any stiff flat and smooth surface, such as the top of a soap or chop box, or a stiff piece of cardboard or triple-ply wood, will suffice.

206. *Plotting Bearings with the Protractor.*—The angle denoted by any graduation trace on the edge of the protractor is that

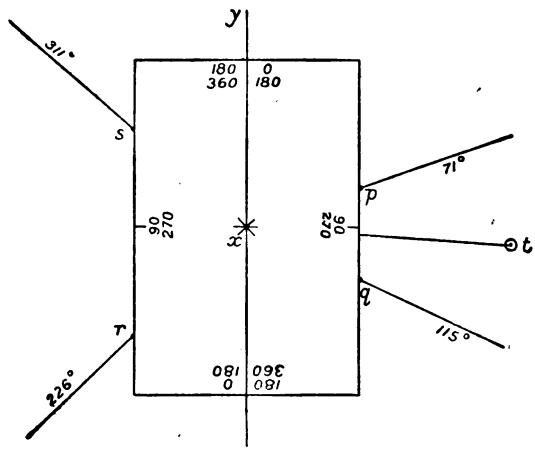

Fig. 52.

contained between the zero edge, *i.e.*, the edge joining 0° and 180,° and a line joining the centre of the zero edge, marked with an arrow-head, to the trace in question.

To plot any bearing between 0° and 180° from any point, draw a line through the point in the direction of north,—true, grid or magnetic as the case may require. Lay the protractor with zero edge along this line, *x y* in Fig. 52, with the arrow-head to the point and the graduated edge to the *right*. Any bearing, such as 71° or 115°, may then be marked off with a sharp pencil.

To plot bearings between 180° and 360°, say 226° and 311°, set the protractor in a similar manner, but with the graduated edge to the *left*.

Note that it is not always necessary to draw a north line through the point from which bearings are being plotted. If north lines

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exist on the paper—such as parallel lines drawn or printed on sketching paper or meridian or grid lines on a map—it is often possible to lay the zero edge parallel to north and south by setting the protractor so that one of these lines cuts its bottom and top edge at graduations symmetrically placed, as in Fig. 54.

207. *Reading Bearings with the Protractor.*—Proceed in a similar way for the reverse process of reading a bearing from a map. If it be required to find the bearing of t from x, Fig 52, join $x\,t$ by a straight line, set the protractor as before with arrow-head at x and zero edge parallel to the north line; then read the bearing where the line $x\,t$ cuts the graduated edge.

It may be noted that the reverse bearing $t\,x$, *i.e.*, x from t, may

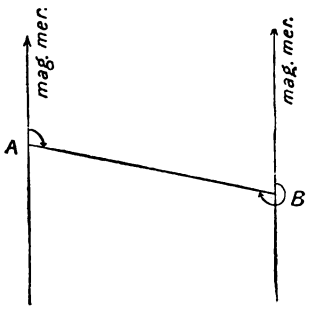

FIG. 53.

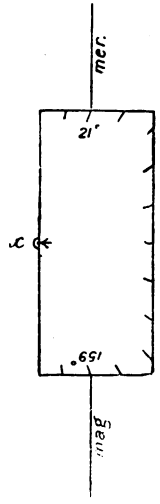

FIG. 54.

if desired, be read at the same time on the other set of graduation figures. Thus, if the bearing $x\,t$ reads 94°, the bearing $t\,x$ is 274°. (*Cf.* Fig. 53.)

§ 57. Compass Errors.

208. *Terrestrial Disturbances.*—The near presence of iron always affects a compass and great care should be taken to withdraw from any mass of iron when taking an observation. The following are minimum safe distances for visible masses of iron :—

Heavy gun	60 yards	Steel helmet	3 yards
Field gun and telegraph wires	40 ,,	Cap badge	½ ,,
Barbed wire	10 ,,	Box-respirator	.... in "slung" position.

Avoid dumps, railroads, tractors, corrugated iron hutments, steel or "rolled gold" spectacle frames, and the like.

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Iron on the surface may be avoided with care; but when it lies below ground it presents a serious difficulty. Pipe lines below streets or buried shells in battlefields may be suspected, but in general there is no means of detecting masses of iron ore—the common cause of error—except by the behaviour of the compass itself.

If there is the least suspicion of disturbance you should shift your position. This is often immediately convincing. Thus at Mt. Magnet in Australia a change of position of only 1 foot has been found to change the bearing by 8°. But the ore may be widespread, in which case a shift of 1,000 yards may not rid you of the disturbance. The following test is helpful, though not conclusive.

Consider the forward (direct) and backward (reverse) bearings of the line A B in Fig. 53 above. The bearings A B at A and B A at B should differ by 180°; if they do not, there is presumably disturbance at either A or B, or at both.

This test is not conclusive, for there might be a disturbance of the same amount at both A and B. Your compass itself, moreover, might be defective. If you are assured there is no fear of disturbance, in a chalk region for example, this is a fair way of testing the compass for internal defect, such as loss of magnetism; to be certain, however, you should test over various lines lying in different bearings and as far apart as convenient. Remember that, as you do not ordinarily read more closely than $\frac{1}{4}$°, a discrepancy of this amount between forward and backward bearings is normal. True tests are made on undisturbed lines of *known* bearing (*vide* Art. 276).

Nickel and cobalt also affect the compass, but in a minor degree.

209. *Other Disturbances.*—The needle is also subject to cosmical influences, which occasionally give rise to magnetic storms. These, however, very rarely cause a change of even 2°. The daily variation of the needle is too small to be considered in this place.

210. *Method of Avoiding Magnetic Disturbance.*—If a round of bearings be taken with a compass at any one station, all of these bearings may be affected by local attraction; but if bearings are read without moving the compass more than a few inches, each bearing will be affected by exactly the same amount, and therefore the *differences* between the bearings will give you correct included *angles*. If, therefore, your work be carried out by plotting angles of triangles instead of magnetic bearings, local attraction will not signify and your work is likely to gain in accuracy.

§ 58. Detail.

(*a*) *Graphic Triangulation.*

211. On a compass as on a plane-table sketch, the apex of a triangle is fixed by the intersection of two direction rays. But on a plane-table sketch, these direction rays are immediately

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transferred graphically to the sheet; whereas with a compass the bearings are observed and read in the instrument and then plotted by protractor.

212. *Ruled Paper.*—The direction rays as given by the compass are magnetic bearings and are therefore generally plotted from lines drawn on the sketch to represent magnetic north lines. Squared paper is then a great convenience; if, however, it be not available, the parallel lines should be drawn by hand and spaced at about the width of the protractor.

(*b*) *Resection.*

213. Since direct and reverse bearings differ by 180°, if we are given the one we can at once deduce the other. *Cf.* Fig. 53.

If the direct bearing lies between 0° and 180°, add 180° to obtain the reverse bearing; otherwise deduct 180°.

The bearings of two or more fixed points from an unfixed resection point may be considered as direct bearings, and if the reverse bearings be deduced, these may be plotted from the fixed points and their intersection will define your position.

For example, suppose in Fig. 55(*a*) that P and Q are two points in nature, that you are somewhere near X and wish to resect

FIG. 55(*a*).

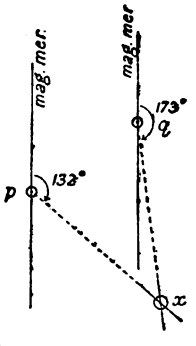

FIG. 55(*b*).

your position. Let the bearings of P and Q be 312° and 353° respectively. The reverse bearings are 312°—180° and 353°—180°, or 132° and 173°. Plot these bearings as shown in Fig. 55(*b*); their intersection *x* defines your position.

It will be observed that resection with the prismatic compass from two fixed points is virtually the same as resection from two fixed points with the plane table and trough compass (*vide* Chapter XIV, Art. 172).

Although bearings of two points are theoretically sufficient for a fixation, it is important to obtain the bearing of a third point as a check.

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(c) *Traversing.*

214. In a plane-table traverse, the directions of the legs of the traverse and of points of detail are obtained graphically, as explained in Chapter XIV, § 52; whereas in a compass traverse all these directions are bearings, are obtained with the prismatic compass, and have to be plotted by means of the protractor. In both cases the lengths of the legs are measured by pacing, in work of the character here described.

In traversing with the prismatic compass, the bearings and lengths of the legs and the bearings to points of detail may be plotted forthwith on the sketch, or may be recorded diagrammatically in a notebook for subsequent plotting. The former method is preferable when time permits, since the sketcher has the ground before him when he actually draws the sketch.

The prismatic compass is more suitable for traversing than the plane table, used without a compass, because, as pointed out in Art. 178, an error in a single bearing is not carried throughout subsequent bearings.

(d) *Method of Sketching Detail.*

215. This is practically the same as described in connection with plane tabling in the preceding chapter, § 53.

§ 59. Relief and Concluding Remarks.

216. *Sketching of Relief.*—This is virtually the same as in the case of the plane table; the methods are described in § 54 of the preceding chapter.

217. *Advantages and Disadvantages of Compass Sketching.*—Prismatic compass sketching may be ranked, as regards accuracy, between plane-tabling and sketching with the cavalry sketching board.

Compared with plane-tabling, it has the advantage that the sketcher is less exposed to view, and that a good deal of the work may be hastily sketched in diagrammatic form, to be completed elsewhere; it has the disadvantages that it is far less accurate and very much slower. It is no advantage that resection can be effected from two points, for this can be done with the plane table and trough compass and with much greater accuracy.

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Chapter XVI.

SKETCHING WITH THE CAVALRY SKETCHING BOARD.

§60. Adjustment and Setting.

218. *Adjustment.*—The board is described in Chapter XII, §42, Art. 144. A blank stretch of paper being unwound and flattened taut, the rollers are clamped by rotating their ends in the direction noted on the board.

The board is suitable for mounted or dismounted sketching. On horseback it should be strapped to the left arm, midway between wrist and elbow; the bridle hand should then be kept high in order to prevent the board from knocking on the pommel of the saddle. Afoot, the straps should be held firmly in the left hand, which should be close up to the back of the board, so that the table may be revolved on the forefinger and thumb.

219. *Setting the Compass.*—Before starting work, the compass should be "set" so that, when the index line on the glass coincides with the needle, the direction of the road runs generally up the length of the paper.

The general direction of the route may sometimes be seen from the starting point; if not, its magnetic bearing may be given, or its true bearing may be taken from a map.

(i) When the direction is seen.—Turn the board so that the "line of direction" marked on it points along the direction of the route. Holding the board steady, move the line marked on the cover of the compass until the knob end is over the north point of the needle.

(ii) When the magnetic bearing is given.—At first ignore the needle. Put the line on the compass cover on the "line of direction," the knob end towards the roller containing the sketching paper which will be unrolled in the course of work; then turn the knob backwards (*i.e.*, by west) through an angle equal to the bearing given. Now when the table is turned until the knob end of the line on the cover of the compass is over the north end of the needle, the board is set.

This may be explained by means of a diagram (Fig. 56).

Here A B is the line of direction on the board, the circle represents the compass and C D the movable line on the cover, with the knob end at C, which is shown on the diagram as in its final or set position. Suppose the magnetic bearing given as the

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general direction to be followed be 40°. Then we wish to arrange so that whenever the board is set, the bearing of the direction line A B is 40°. To do this we move the line on the cover so that it coincides with the line of direction A B, the knob pointing the way we wish to go. Then we move the knob end of the line 40° to the west, or in the reverse direction to the readings on the compass box. Now, whenever the board is turned so that the magnetic needle coincides with the line C D, the north point of the needle being under the knob C, C becomes the magnetic north and the bearing of the line of direction A B becomes 40°, which is what we want.

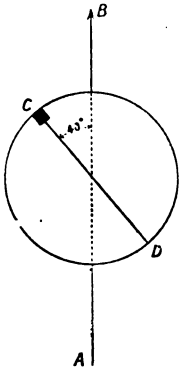

FIG. 56.

If in the course of the work the sketch runs off the paper, reset the compass and start afresh, having drawn a line right across the paper and marked the ending and restarting point A in each portion. Be careful to mark the north point on each section of the sketch.

§61. Procedure and Use.

220. *Rules for Sketching.*—The following rules should be observed when sketching, either mounted or dismounted, with the cavalry sketching board :—

i. Turn the horse, or body if dismounted, in the direction of the object.

ii. Revolve the board until it is " set " by the compass.

iii. By moving the left arm or hand to the right or left, bring the point marking your position, whence the line showing the new direction is to be drawn, *immediately under the eye.* Now align the ruler from this point in the required direction, and, placing the pencil point at it, draw the line *away* from you. It is well to take a second look at the compass at the moment of drawing the line, so as to guard against the board having been moved while the ruler was being aligned on the object.

Any slight alteration of the position of the board, in order to obtain a more exact coincidence of the needle and the index line, is best accomplished at this juncture by gently turning the left wrist and forearm.

The correct alignment of the ruler on any distant point is a matter of judgment and " eye." With a little practice the ruler can be aligned, and the direction drawn in, correct to within 2° or 3°, in between 10 and 20 seconds.

Most horses soon get accustomed to the work, and will stand steady enough for a brief period immediately after being reined up.

After a little practice the ruler can be dispensed with, except for long " shots," and the directions of objects drawn in by

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placing the pencil point at the place representing the position of the observer and drawing a line in the required direction.

The *forward bearings* should be taken to the farthest *visible* parts of the route, irrespective of distance.

221. *Distances and Heights.*—It is best to measure distances by taking them from a time scale.

Allow 12 miles an hour for a canter,
8 ,, ,, trot,
4 ,, ,, walk,

under normal conditions. Practice in keeping the horse at an even pace is essential.

The construction of a time scale for trotting at 8 miles an hour is described in Ex. 10, Art. 17, § 7, Chapter III. The best pace at which to work is a steady trot. If it is known that the particular horse which is being ridden has not got the normal speeds, a special scale should be made.

In using the above scale at the walk, halve it. When walking half the time and trotting the other half, take three-quarters.

In settled weather an aneroid barometer may be used for fixing levels. (*See* Chapter XII, § 43, and Chapter XIV, § 54, Art. 201.)

The clinometer on the back of the board is of use for rough measures of slopes in the vicinity of the sketcher.

222. *General Remarks.*—Accurate work is not expected with this instrument, but for executing a rapid reconnaissance on horseback, where a fair sketch only is required, its handiness makes it eminently useful; for such a purpose the route should be simply "traversed," as described in Chapter XIV, § 52. The position of prominent points off the route may be fixed by intersections, taken from stations on the route, the positions of which have been fixed by traversing.

The principal use of a horseback sketch executed as above is to serve as a diagram to illustrate a road report. The report being the essential part of the work, the sketcher must make notes as he rides along, and must generally be on the alert. It is, therefore, not desirable to count paces, for this system is vexatious and laborious and prevents the sketcher from studying the country through which he rides. For the above reasons the best way is to measure distance by *time*.

The cavalry sketching board is also very useful for work on foot, particularly when completing a previously prepared enlargement (*see* Chapter XIX). It may also be used for making a road report on foot or on a bicycle. The methods in this case are similar to those described above, distances being measured by pacing or by counting the revolutions of a cycle wheel. In the latter case it is necessary to ascertain beforehand the distance covered by one revolution, and to prepare a scale of cycle revolutions accordingly. Suitably attached to the handle-bar of a bicycle provided with a ground rest, the board will prove itself particularly serviceable.

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Chapter XVII.

EYE AND MEMORY SKETCHING.

§62. Eye Sketching.

223. *Purpose.*—Although it is improbable that an officer unprovided with instruments would be required to sketch a large area of country, it may happen that on service, he will find it necessary to send in a plan of the country in the immediate vicinity of his post. For instance, as officer in command of an outpost company, he would probably have to furnish to his superior officer a sketch of the ground on which his troops were disposed. Moreover, a plan-sketch is a useful addition to any written report.

Without any instrument whatever, it is possible to execute, with fair accuracy, a plan-sketch which from a military point of view may prove of considerable value. The making of such a sketch is much facilitated by the mastering of the principles of sketching described in Chapters XIV and XV.

224. *Materials.*—The sketcher requires a pocket book, such as Army Book 153, or a flat board, and ruler.

Board.—A piece of board of convenient size, a smooth-covered book, the lid of a biscuit tin, or any similar article to which a sheet of paper can be attached. (To keep the paper stretched over the board, or other article, perhaps the simplest way is to secure it with two pieces of string, tied tightly round paper and board at either end.)

Ruler.—A slip of wood, or stout cardboard, with a straight edge.

Not being provided with a protractor or a scaled ruler, the sketcher must construct a scale to which to draw his sketch. The scale to be adopted for any sketch depends on the area of the country to be sketched, and on the size of the sheet of paper available. Assuming that the maximum area required is a square mile, the scale can be a comparatively large one; for even an ordinary pocket book (such as Army Book 153) would permit of this area being drawn, on a single page, on a scale of 4 inches to 1 mile. In most officers' pocket books squares of a certain size are ruled on the pages; *e.g.*, in Army Books 152 and 153, the squares are $\frac{1}{4}$ inch. If, therefore, a book of this kind is available, a ready-made scale is at hand, otherwise a scale must be thought out.

The sketcher should decide on what he thinks will be a suitable length to represent 100 yards, or other distance, and mark it on the edge of his improvised ruler, as well as on the edge of a slip of paper. By moving the latter along the ruler's edge as many lengths of 100 yards, or other distance, can be marked off

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as are considered necessary. The divisions should be numbered as usual, and the scale should be drawn at the bottom of the sheet of drawing paper. If at some future time a foot rule, yard measure, or anything of the kind, divided accurately into inches, is forthcoming, the number of yards to the inch can be discovered and a representative fraction worked out.

It is useful to remember that the lines on a sheet of ruled foolscap are as nearly as possible one-third of an inch apart. So a strip of such paper, cut lengthways, makes a handy scale, the intervals between the lines being approximately equal to 100 yards on the 6-inch scale, 150 yards on the 4-inch, 200 on the 3-inch, 300 on the 2-inch, and 600 on the 1-inch. Another useful measurement to know is that the diameter of a halfpenny equals one inch.

225. *Execution.*—The sketch is executed by first arbitrarily fixing on the paper a point to represent the position of the sketcher.

Then, pivoting his ruler on the point thus fixed on the sketch, he aligns the ruler on distant points, and draws rays on his sketch in their direction.

It is necessary for the sketcher to get his eye well down along the alignment of the ruler so that the direction of the ray may be obtained as accurately as possible.

The detail required on the sketch is filled in before the sketcher moves from his position. Having completed this, he marches in the direction of a point whose direction is fixed by a ray on the paper, and plots to scale along this ray the distance traversed.

In order to set his sketch for further work, he must align this ray on the back station, from which he has come. He then proceeds as before to obtain intersections, and fills in the detail to be sketched in around his new station.

§ 63. Memory Sketching.

226. It will often happen on service that reconnaissances have to be made under conditions which make any sketching on the ground impossible. In such circumstances a memory sketch will often furnish a useful complement to a report. When possible, rough notes as to direction, distances, and the shape of the ground should be made during the reconnaissance in order to assist the memory, but it will be found that with practice a fair representation of the ground may be drawn without any notes at all.

In observing ground with a view to making a sketch of it subsequently from memory, it is important to distinguish between the essentials for the purpose of the reconnaissance and details of minor importance. No attempt should be made to burden the memory with the latter.

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Chapter XVIII.

PANORAMA DRAWING.

§64. Preliminary Considerations and Study.

227. *Definition of Military Panorama.*—A useful branch of field sketching is the representation of a landscape in a conventional form, or the art of representing the country in elevation instead of in plan. Such sketches, which are called "panoramas," are often of great value to illustrate a report, especially upon an artillery position.

It may be premised that, from a military point of view, it is not necessary to be an artist to produce a useful panorama. Indeed, it is almost better that the artistic sense should be absent, and that instead of idealizing a landscape, it should be looked at with a cold, matter-of-fact military eye. Thus the sketcher would note rather the capabilities of the country for military purposes than its beauties of colouring or the artistic effects of light and shade.

The beginner often feels much discouraged because his first attempts are so unlike what he wishes to draw; but with patience and practice and a close attention to the hints in this chapter, he will find that in time he will be able to produce useful work. Let it be understood that, however rough the picture may be, it will still be useful if intelligently drawn. Another difficulty is that of drawing the trees, houses, &c., as they are seen in the landscape. Absolute accuracy in the details of their appearance is not essential. So long as the sketcher can faithfully produce the outline of the important military points of the panorama, the other details can be drawn in a conventional manner. It is better to stick to bare outline as far as possible and leave shading alone, except such as is required to indicate distance in a conventional manner. Unnecessary shading in a panorama tends to confuse and detracts from its clearness.

228. *Preliminary Study.*—Let the beginner learn by degrees, drawing small and easy subjects to commence with, before trying anything too ambitious. Let him copy other drawings, and thus gain confidence in his own powers. Plate XXII shows some examples of methods of drawing objects in nature in a conventional manner.

The sketcher should study the ground very carefully before commencing to draw it. He should make a free use of the field glasses or telescope to assist in resolving details which appear confused and in defining accidents of ground that are not clear to the naked eye. The more carefully the country is studied beforehand, the easier will it be to draw it.

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In commencing to draw a panorama, the first thing to do is to choose a suitable point of view from which to sketch it. This depends on two things :—(*a*) The extent of country to be included in the panorama, and (*b*) a position from which a good view can be obtained. In a measure, these two conditions are closely associated. The wider the extent of the panorama, the further off must be the position from which it is drawn. It will be understood that the wider the visual angle, the more inconvenient it is to draw all that it includes, and it may thus be necessary to make a panorama of the country in two or more sections and to join them together afterwards.

§65. Procedure and Methods.

229. *Initial Considerations.*—In beginning the sketch the points to be considered are as follows :—

(1) How to keep the dimensions of the picture proportionate to the apparent dimensions in nature. We shall regard this as the question of *framework.*

(2) How to overcome the difficulties of perspective and get a "receding effect" for distant objects.

(3) What to insert and what to leave out.

(1) *Framework.*

230. An area of country included in an angle of 30° can be conveniently sketched on a piece of paper 6 inches by 4½ inches, and a sketch of this size can be made on a page of Army Book 153. Squared paper such as that of this book is of great assistance to the beginner.

231. *Dimensions of the Picture.*—The first thing to do is to fix the length and breadth of the panorama. If we suppose that a piece of glass (or celluloid) is available and if we hold it at such a distance from the eye that the country to be sketched is covered by the glass, we could mark on the glass the corners of the sketch and we could also indicate in their correct position all the prominent points and principal features. We could, in fact, draw the whole panorama, for the whole panorama would be outlined in the same plane.

The operation would be much facilitated if the glass were divided into squares. It is evident that it should always be held at the same distance from the eye, and this might be ensured by passing a piece of string through a hole in the glass and holding the end in the teeth.

Some opticians make a special form of view-finder to show photographic fields of varying dimensions, adjustable at will. This may be found of assistance.

232. *Measuring Dimensions with a Ruler.*—In the absence of squared glass, measurements should be taken with a pencil or a

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ruler, or with the protractor, the uniform distance in each case being maintained by a piece of string.

Let a piece of string be passed through the holes in the protractor ("A" Mk. III) and tied so as to be a little more than 27½ inches in round length. Now if the string is held nipped in the teeth and the protractor is pushed directly from the face until the string is taut, the eye should be exactly 11 inches from the centre of the upper edge, which is to be that of the 1/20,000 metric scale. Then every division of the scale will subtend at the eye an angle of 1°, the whole length of 25 divisions containing 25° to a sufficient approximation.

To measure the length of the sketch with a ruler let one end of the ruler coincide with the left edge of the country to be sketched and move the thumb till it coincides with the right edge. Mark off on the paper the horizontal limits, thus measured, and then measure and mark the vertical limits in the same way. If you are not using Army Book 153 or a squared block, divide the oblong you have obtained into squares to help you to fix the prominent features, named "ruling points" in work of this class. Fix a certain number of ruling points, first on the skyline and then in the middle distance and foreground, by measuring with a ruler their distance from the sides and from the top or bottom of the sketch.

The process of measuring with a ruler is easier if it carries a convenient scale to which the squares on the sketch are then figured to correspond.

As an illustration of the framework and ruling points, Plate XXIII may now be examined.

233. *Measurement by Compass.*—The above method of fixing the framework and ruling points is the simplest and has the advantage that no instruments are required. It is, however, possible to fix guiding lines by compass bearings if preferred. Take bearings to objects on the right and left edges of the country to be sketched, and draw vertical lines at the right and left edges of the paper to represent these bearings. Suppose the angle subtended by this landscape to be 30°; then vertical lines are drawn subdividing the sketch into strips, each of which subtends 5° or 1° or any other such number of degrees as may be convenient. The bearing of any object can then be taken and its horizontal position fixed in the framework.

The advantage of this method is that bearings are always useful from a military point of view. It will be observed on Plate XXIII that the bearings are given in two ways. For the artillery the bearing is given right and left of a central point, which in the panorama shown is a large isolated tree. For general purposes, the grid bearing, or, if there is no grid, the magnetic bearing, should be indicated as on the second horizontal line of the sketch.

234. *Measurement with Field-glasses.*—When field-glasses are fitted with a graduated reticule, angles from the central point, or from the right or left margins of the picture, can be measured

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directly and with considerable precision. The number of degrees, (a $\frac{1}{2}^{\circ}$ graduation is commonly used), is read off immediately between one object and another; and thus the whole landscape may be measured, piece by piece, vertically as well as horizontally.

Vertical angles can also be measured by clinometer, but one of the methods described above will usually be preferred in work of this class.

235. *Inserting Principal Features.*—Having obtained the framework, the next step is to connect our ruling points by drawing in the main features. First insert the skyline and then the other principal objects, such as roads, rivers, hills, &c. These should be shown by single light lines only, the finishing touches being left to a later stage.

236. *Measurement of Slopes.*—Care should be taken not to exaggerate the side slopes of hills, and until a sense of proportion has been developed the slope should be measured. A circular celluloid protractor, if available, affords a very simple means of measuring a slope.

A plan recommended is to hold the sketch upright, its upper edge horizontal, the longer edge of the Serv. protractor projecting above the book or block. Now tilt the protractor till its upper edge is in alignment with the side slope of the hill and draw the slope along its lower edge as a guide to the inclination on the drawing.

237. *Exaggeration of Vertical Scale.*—The preceding description assumes that the panorama is drawn with the horizontal and vertical scales the same. For some landscapes, however, it is better to exaggerate the vertical scale to about $1\frac{1}{2}$ times the horizontal; all vertical measurements must then be increased in the proper proportion. If the squares on your paper are converted into rectangles of which the vertical side is $1\frac{1}{4}$ or $1\frac{1}{2}$ times the length of the horizontal, the necessary exaggeration will be effected automatically.

Paper with rectangles of this nature has been prepared by some of the military schools.

(2) *Perspective.*

238. Having fixed the general framework, consisting of the network, the ruling points and principal features, and having decided what we want to show, we can now prepare to complete the sketch.

The chief difficulty experienced by the beginner is to exhibit the "receding effect" in his picture—in other words, the perspective. A close attention, however, to the following simple rules will overcome this difficulty quite sufficiently for military purposes.

Firstly, as regards the size of the objects. It will be noticed in looking at the landscape that, as objects are placed further off, they appear smaller; therefore make them so in drawing the panorama.

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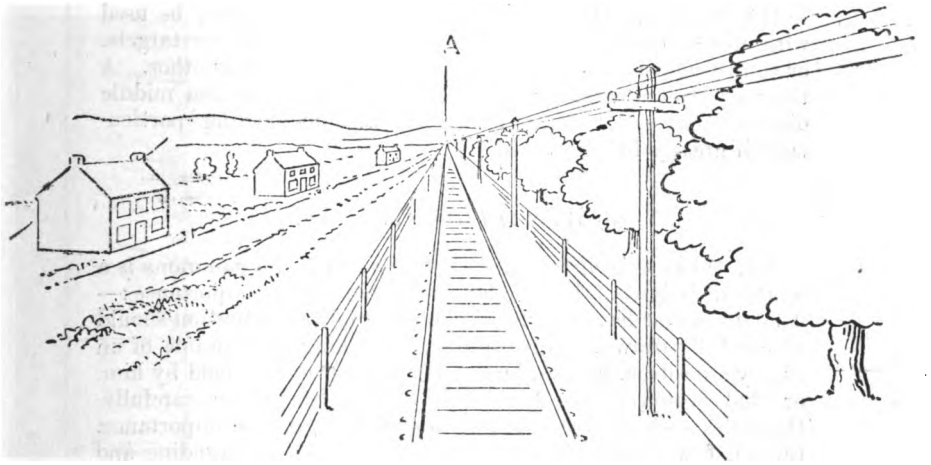
The farther off the details in the country are, the thinner must be the lines with which they are drawn. Thus—

In drawing the nearest part of the picture, use a medium pencil with thick strokes.

The middle distance, which lies between the foreground and the background, should be depicted in strokes of medium thickness, or with an ordinary pressure.

Lastly, the background, or far distance, should be drawn in fine strokes with a hard pencil or with one used with a very light hand.



A simple Example of Perspective:
the vanishing point A to be specially noted

FIG. 57.

In short, the nearer an object is, the thicker and heavier the strokes with which it is drawn, and the farther off it is situated the thinner and lighter must be the strokes.

The height of the vanishing point may be about two-thirds of the height of the picture if the foreground is not too high and the distant objects are remote. If the foreground is high and the distance not great, the point may be only one-third of the height.

239. *Application of Rules.*—Observing these principles, begin, therefore, with the background and work gradually towards the front where the blackest and thickest strokes are used.

Every feature sketched, whether natural or artificial, should be shown in outline in the simplest way possible. So long as the object can be immediately identified the less detail or shading there is the better.

The relative size of objects is of great importance. There is a natural tendency towards exaggeration of objects, such as houses, in the distance, which makes them appear nearer than they really

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are. Features in the background are shown quite conventionally; in the foreground the actual shape of trees and buildings will be suggested.

There is also always a tendency to exaggerate the heights of hills; this must be avoided, as it leads to misrepresentation.

Plate XXII shows conventional methods of depicting various objects, natural and artificial, and contains elementary examples of perspective.

240. *Shading.*—Do not show shadows. Shading may be used with discretion to emphasize special objects, such as targets, or to distinguish features in one plane from those in another. A river or stream winding through meadow land in the middle distance may not be clearly followed without shading, particularly if greatly foreshortened.

(3) *What to Include and Omit.*

241. What to include and what to leave out of a panorama is a matter of judgment, but the following points are of importance:—All details that have any bearing on the military situation should be carefully drawn. For example, in making a panorama of an enemy's position, hedges, fences, &c., that would be held by him, or that would assist an attack, should be put in carefully. Obstacles such as rivers, marshes, and so on, are of importance. Church towers and steeples, factory chimneys, outstanding and easily recognized trees, such as poplars, being landmarks, are useful. Woods should also be included. The foreground, *i.e.*, the ground immediately in front of the sketcher, is rarely of tactical importance, and, except when it is, it should be omitted. The drawings of villages should not contain the complete details of every house, but should show rather the general shape and extent; but the outlines or even details of every building used as a landmark, sniper's post, enemy observation post, or such like, should be indicated with sufficient care to render them readily recognizable.

These are not all the points to consider, but they exemplify the general procedure to be followed.

§66. Finishing the Sketch.

242. In finishing a sketch do not aim at artistic effect, but at showing all objects of military importance with clearness and precision.

Colours are very useful for giving finish and clearness to a sketch. Red chalk should be used for buildings, blue for water and brown for roads. Drawings which are intended for reproduction should not be coloured.

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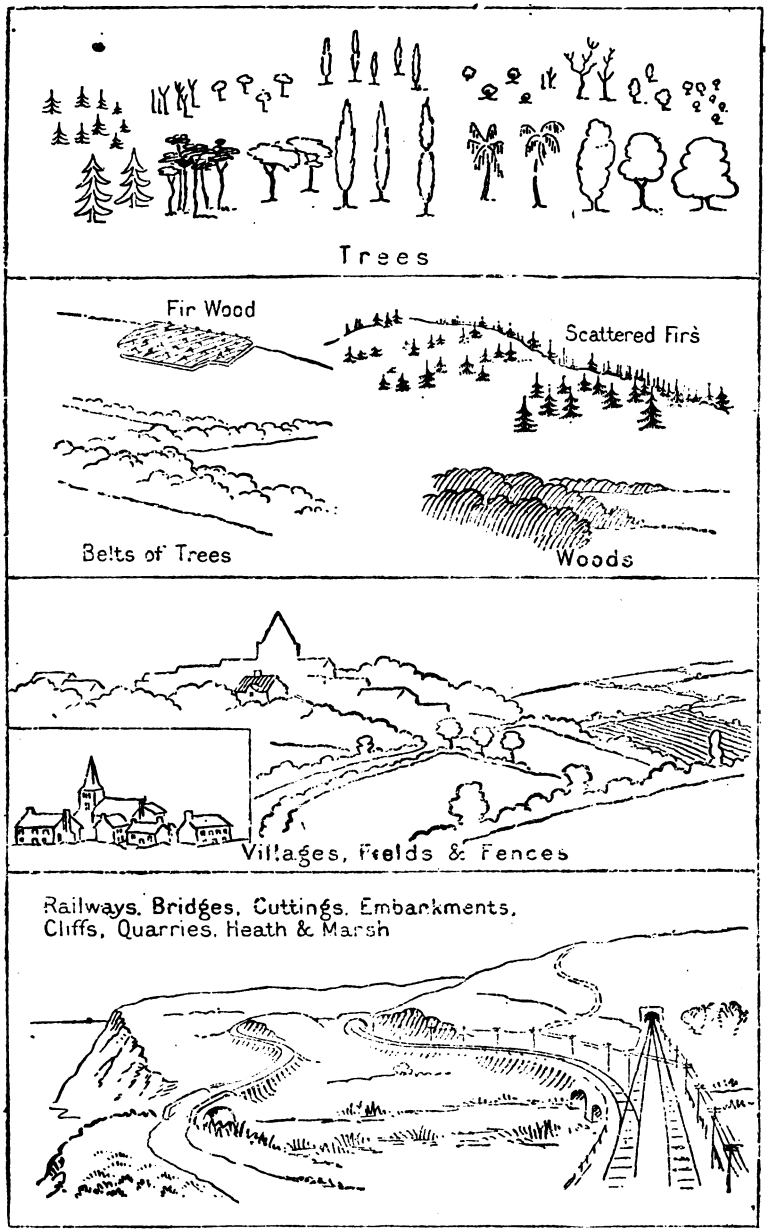

PLATE XXII.

Conventional Methods of Showing Landscapes.

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243. Every panorama should have *References* and *Headings* as follows :—

(*a*) The position from which it was made, and, if possible, its height above M.S.L.

The height of any tree or building from which the sketcher may have worked should be added to the ground level.

(*b*) The names of all the principal places so far as they are known, and any descriptions which would elucidate the sketch.

Names and descriptions should be written clear of the sketch, with dotted lines drawn to the object. It is useful to give ranges or distances, but if ranges are given, the means of ascertaining them must be stated, whether by range-finder, or estimation, or from the map.

(*c*) It is a useful plan to attach to a panorama a map showing the position from which it was taken and the arc included.

Whether the map is attached or not, the map positions of the sketching post and the central point of the picture should be set forth on the panorama. (*See* Plate XXIII.)

(*d*) Whether the framework was constructed by bearings or not, at least two bearings should be given.

In panoramas for artillery use, the bearing from the station to some central object should be given, it being stated whether the bearing is magnetic, true or grid ; and the other bearings will be shown as reckoned left and right of this central bearing as zero. If true or grid north is derived from the compass, the variation adopted should be stated.

(*e*) Every sketch must bear the name, rank and regiment of the sketcher ; the date, hour and state of the weather, especially the degree of visibility, whether good, fair or bad.

(*f*) If a report is attached to the sketch, those features to which reference is made should be lettered or numbered.

244. *Specimen of Panorama.*—Plate XXIII is an example of a well-drawn panorama in fairly close intersected country, and may be studied with advantage. The chief points to notice are the varying strength of line, from the foreground to the extreme distance ; the simple treatment of the buildings, in which no attempt is made to show windows or other small details ; and the

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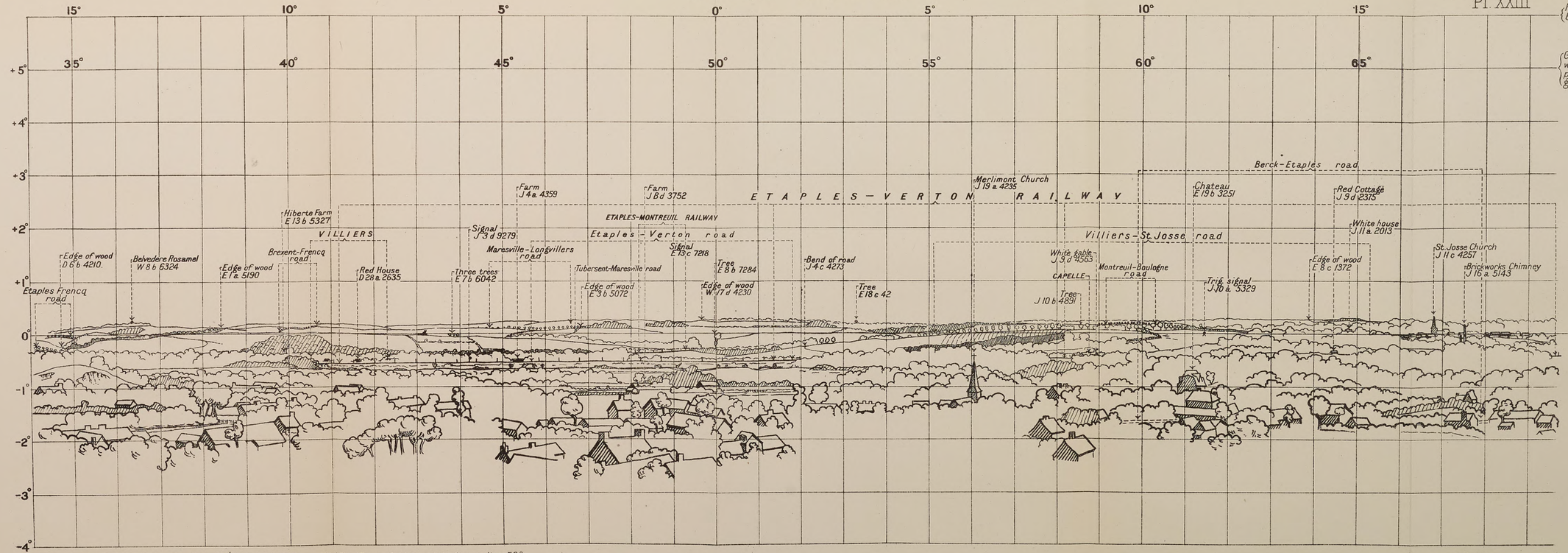
TYPICAL PANORAMA

Pl. XXIII

For artillery work bearings are given thus.

Grid or magnetic bearings. Not written as a rule on artillery panoramas but should be given on all others.


15° 10° 5° 0° 5° 10° 15°
35° 40° 45° 50° 55° 60° 65°
+5° +4° +3° +2° +1° 0° -1° -2° -3° -4°
Edge of wood D 6 b 4210.
Belvedere Rosamel W 8 b 6324
Edge of wood E 1 a 5190
Etaples Frencq road
Hiberte Farm E 13 b 5327
VILLIERS
Brexent-Frencq road
Red House D 28 a 2635
Three trees E 7 b 6042
Signal J 3 d 9279
Maresville-Longvillers road
Farm J 4 a 4359
Tubersent-Maresville road
Edge of wood E 3 b 5072
Farm J Bd 3752
ETAPLES-MONTREUIL RAILWAY
Etaples-Verton road
Signal E 13 c 7218
Tree E 8 b 7284
Edge of wood W 17 d 4230
Bend of road J 4 c 4273
Tree E 18 c 42
ETAPLES-VERTON RAILWAY
Merlimont Church J 19 a 4235
Villiers-St Josse road
White gable J 9 d 4563
CAPELLE
Tree J 10 b 4891
Montreuil-Boulogne road
Berck-Etaples road
Chateau E 19 b 3251
Trig signal J 10 a 5329
Red Cottage J 9 d 2315
White house J 11 a 2013
Edge of wood E 8 c 1372
St Josse Church J 11 c 4257
Brickworks Chimney J 16 a 5143

View looking N.E. from Observation Post 44d N.W.1. 24d. 1289. Height 15 m.: Grid bearing of zero line 50°.
Date: July 3, 1918. 0900 hours: weather fine: visibility good.

J. Smith,
Lieut., R.A.

Truscott, London.

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use of shading, confined to showing up the buildings and to distinguishing a few woods and tree clumps, which help the eye to pick out the distances.

The treatment of the dense mass of trees in the right half of the view is especially instructive. The student would probably find such a subject very difficult and confusing, and would not know where to begin. The artist has selected a few groups of tree tops, and, while varying his touch, has used very few lines and avoided any over-elaboration. It will be seen that the result is very effective, and gives an excellent suggestion of a dense mass of foliage.

The key-note of this drawing is simplicity. The essential lines alone are drawn, and the result is that objects, however small, stand out clearly, because they are not confused with a mass of irrelevant detail.

§67. Telescopic and Photographic Panoramas.

245. *Telescopic Sketch.*—The telescopic sketch, as it may be called, has yet to be considered. This is a sketch which is made by the help of a telescope or good field glasses of a distant piece of country, of which the details cannot be seen by the naked eye. At first this may seem difficult, but practice will soon overcome it. First the subject should be looked at carefully with the naked eye, and an outline enlargement of it should be made on the paper. Then the detail should be filled in bit by bit with the aid of the telescope. The telescope should be on rests, and the paper directly under the eyepiece, so that after studying the subject through the telescope the sketcher can look at once on the paper and draw in what he sees.

Telescopic sketches are useful for the identification of targets such as snipers' posts, machine guns, batteries, &c.; the sketcher must endeavour to show clearly the positions of the more prominent features of the adjacent landscape relative to these objects, ordinarily invisible to the unaided eye.

It is important that the prominent features marked as indicators of the direction of the target should be as nearly as possible at the same distance as the target; otherwise the sketch will be probably useless at any spot other than the original post of observation.

246. *Periscopic Sketch.*—In trench warfare sketches are often made through a telescope or periscope or a combination of both. Sketching is then simplified, since the field of view is fixed and is commonly very small. It may be necessary to sketch each portion of the field in succession in order to obtain the whole landscape required.

247. *Photographic Method.*—Though not strictly within the province of this chapter, it is advisable to make some mention of photographic panoramas. These were developed to a great extent in the late war, and during trench warfare replaced in

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large measure the hand-drawn sketch. There is no doubt that photographic panoramas will always play a part in future warfare, but they can never wholly take the place of the drawn panorama, which has certain advantages not possessed by the photograph.

As a broad generalization the difference between the two kinds is that the photograph cannot select, but represents everything (so far as atmospheric conditions permit) precisely as it is at the moment. This characteristic makes it inferior to the hand-drawn sketch when it is a question of presenting rapidly and clearly the main military features of the landscape. On the other hand, for prolonged study of detail and for faithful record of the minutiæ in the landscape, the photograph is superior.

The intelligently drawn sketch or panorama will always remain a most valuable adjunct to a report, and its great value in training a man to be observant, and in teaching him the features of the country, should not be obscured by the supposed advantages of any mechanical process.

Ground panoramas have commonly the disadvantage of giving inferior command over hostile lines. In this respect the aerial panorama, taken photographically in an aeroplane, is of the utmost value.

The student may consult the following works:—

Map Reading and Panorama Sketching. By AN INSTRUCTOR. LONDON; Sifton, Praed & Co., Ltd., 2nd Ed., 1917.

Landscape Sketching for Military Purposes. By Captain A. F. U. GREEN, R.G.A. London: Hugh Rees. Ltd., 1908.

Military Landscape Sketching and Target Indication. By W. G. NEWTON, A.R. London: Hugh Rees, Ltd., 1916.

Map Work. By V. SEYMOUR BRYANT and T. H. HUGHES. Oxford: Clarendon Press, 1918. [An elementary manual.]

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Chapter XIX.

COPYING, ENLARGING AND REDUCING MAPS WITHOUT APPARATUS, AND ADDING TOPOGRAPHICAL INFORMATION TO ENLARGEMENTS ON THE GROUND.

§68. Copying a Map.

248. Maps which are to be simply copied without reduction or enlargement may be first traced on tracing paper, and then, a piece of carbon paper being placed between the tracing and a clean sheet of paper and both very firmly fastened down by drawing pins, the tracing may be transferred by following the lines with a pointed instrument.

In the field, an excellent substitute for carbon paper can be made by rubbing lead pencil dust on a piece of tracing paper; in fact, this is to be preferred to carbon paper. Any sharp piece of wood will do for the tracing instrument.

A map may also be transferred direct without a tracing; but there is some danger of damaging the original with the point.

Tracing cloth is useful for copying: it is tough and will bear much handling. Draw on the glazed side, and put washes of water colour, if required, on the back, darker than they are intended to appear on the front.

§69. Enlarging a Map.

(a) By Squares.

249. When it is required to enlarge a map, squares of any convenient size may be drawn on the original, and the paper on which the new map is to be made ruled with squares whose sides bear the required ratio to the sides of the squares on the original. The original is then copied by eye, so that objects occupy the same positions relatively to the squares as they did in the original. (*See* Figs. 58(*a*) and (*b*).)

Ex. 1.—It is required to enlarge to 4 inches to 1 mile a map on which the scale is $\frac{1}{2}$ inch to 1 mile. Squares, $\frac{1}{4}$ inch sides, are drawn on the map. Then to find the length of sides of squares on the enlargement, we have :—

$$\tfrac{1}{2} : 4 :: \tfrac{1}{4} : \text{Length required};$$

whence side of squares required = 2 inches.

Ex. 2.—A plan with R.F. 1/100,000 is to be copied at 4 inches to a mile. Squares, $\frac{1}{4}$ inch sides, are drawn on the plan.

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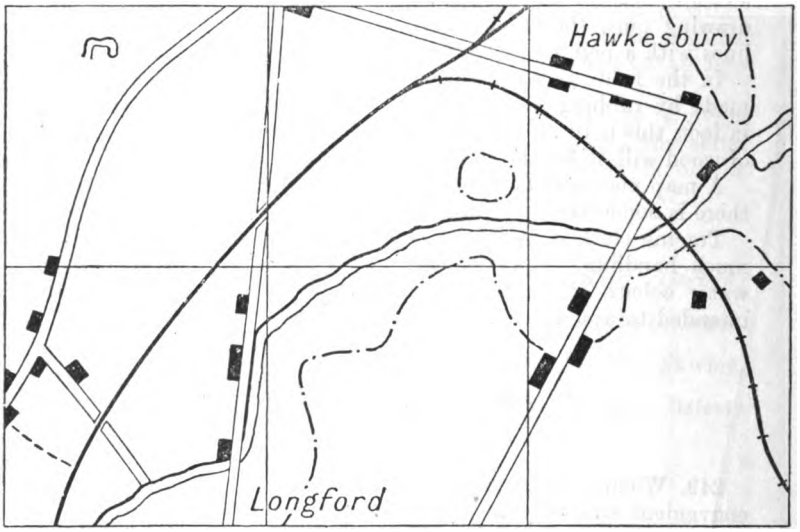
The R.F. of 4 inches to 1 mile being 1/15,840, the length of sides of squares on the copy is obtained by proportion, thus :—

$$\frac{1}{1000} : \frac{1}{15840} = \frac{1}{4} : \text{Length of enlarged side ;}$$

whence the length of a side of the enlarged square is 1·58 inches.

FIG. 58(*a*).

Portion of ½" Map of ENGLAND



Enlargement 4 inches to 1 mile.

FIG. 58(*b*).

(*b*) *By Union Jack Method.*

250. On the map describe a rectangle of sufficient size to embrace the portion to be enlarged, and let this rectangle be represented by *abcd* in Fig. 59(*a*). On the paper on which the enlargement is to be drawn, construct a similar rectangle ABCD, Fig. 59(*b*), such that AB : *ab* and BC : *bc* are each equal to the required ratio of enlargement, this ratio being obtained in exactly the same way as in the preceding Article.

Next divide both the original and enlarged rectangle into four other rectangles by joining the middle points of opposite sides ; and draw the diagonals of all these rectangles as shown by continuous lines in Figs. 59(*a*) and (*b*). The original map is then

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copied by eye, so that objects occupy the same positions in the triangles of the enlargement as in the triangles of the original.

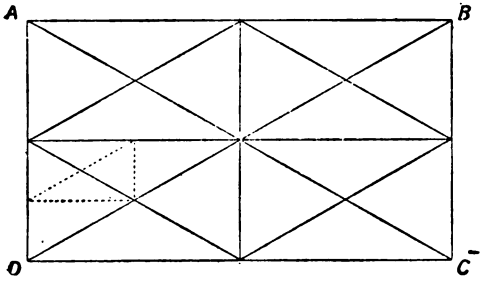

FIG. 59(*b*).

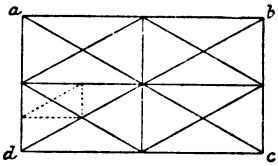

FIG. 59(*a*).

If in certain parts the triangles are too large, they may be broken down still further, as shown by dotted lines in the two figures; but this should not be overdone, as too many lines are apt to obscure the detail.

251. *General Remarks.*—Enlargement of maps is often useful, but enlargements should be made and used with caution and a proper sense of their value and their limitations. The following points must be borne in mind :—

In the first place, mere enlargement adds nothing to the information given on the map, which remains precisely the same as on the small-scale original. In the second place, the details on a small scale are of necessity generalized and in some cases exaggerated; so that it will be found that the roads, for example, are absurdly wide, and that houses alongside are consequently thrown quite out of position, besides being often of doubtful shape.

These distortions place a limit on the amount to which a map can be usefully enlarged. It is seldom that a magnification greater than 4 serves any useful purpose.

Enlargements may be useful for two reasons: (1) to serve as a basis for correcting and adding detail, and so save time in making a military sketch; and (2) to provide room for writing notes and descriptions. A good enlargement from an accurate map may, in the hands of a skilled sketcher, be of considerable value for the first purpose; but in unskilled hands enlarging may prove a snare.

A few general hints may be useful. The framework for enlargement is more rapidly made by the "Union Jack" method, but with the method of squares work is probably more accurate and subsequent work easier. If squares are adopted time may be saved by using squared paper, as in A.B. 153, or such as may be purchased from stationers; but be assured that it is truly squared. The framework on the original particularly must be drawn with the greatest care, since any error will be magnified in the enlargement.

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In the process of enlargement, it is an aid to note where prolongations of straight features cut the sides of squares or triangles or intersect other features. Similarly, watch should be kept for features which are in the same straight line with one another.

NOTE.—This Article may be studied in conjunction with Chapter XXII on Reconnaissance Reports and the sketches made for them, in which the use of enlargements is again mentioned.

252. *Organized Sketching.*—Where several sketches are to be employed to produce a combination sketch with rapidity, the sketchers should not make their enlargements independently. One sketcher should make an enlargement for the whole area. Lines should then be drawn dividing up the whole into sheets; one sheet for each sketcher. A tracing should be made of each man's portion, so that, when he fills it in, his work will be based on a skeleton which is uniform with neighbouring sketches; sheet edges will then be in general agreement with one another.

§70. Reducing a Map.

253. A map may be reduced by the method of squares or the Union Jack method, in exactly the same manner as an enlargement. The discussion in §69, Arts. 249 and 250, should be read in conjunction with this paragraph.

§71. Adding Topographical Information to an Enlargement.

254. *Use and Limitation.*—In future wars it may be expected that officers will be in possession of small-scale maps. These may be all that are required by the nature of the campaign, or they may be all that are available pending the provision of large-scale maps.

It is not possible on a small-scale map to indicate satisfactorily the positions of small bodies of troops, nor to give detailed tactical and topographical information. Occasions will often arise, therefore, when a map or sketch on a larger scale is necessary, and this may be obtained by enlarging the small-scale map. It will then be necessary to ensure that the information on it is correct, and to supplement it by sketching in and writing additional matter which may be required for the tactical object in view.

A map produced by this means cannot be regarded as a substitute for an accurate large-scale map, such as is required for modern warfare against a civilized enemy,—a map which can be prepared by proper survey only; but it will serve many useful purposes. The process of enlarging and adding extra information is consequently of great practical value, and should form one of the primary subjects of instruction.

255. *Filling in Detail.*—Where the map contains a number of well-defined features, the position of which can be fixed upon

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the enlargement, the details of the country between such points can usually be sketched in by eye without difficulty. When, however, the map contains few features the position of which can be definitely fixed on the enlargement, it will usually be necessary to fix some additional ruling points either by triangulation or by traversing as described in Chapters XIV and XV.

The beginner should select some point, the position of which can be fixed from the map as a starting point, and from this complete a framework of sufficient ruling points to enable him to fill in the intervening detail by eye. As he acquires skill he will be able to complete the detail at each point before leaving it, so that he need not go over the same ground twice.

256. *Relief.*—Before interpolating form-lines, the contours which already appear on the enlargement should be visualized on the ground in relation to points of detail.

Note particularly that the enlarged contour, like the detail, is generalized on the small-scale map; and that, though its position as a whole may be right, it will require modification and correction to show the ground formation truly on the larger scale.

Further details of the ground features are shown by the interpolation of form-lines between those obtained from the enlargement. For example, if the enlargement shows contours at a vertical interval of 100 feet, intermediate 20-feet form-lines can be sketched in by eye.

The beginner should place himself at some point on a contour which has been obtained from the map, preferably high up on a spur from which as good a view can be obtained as possible. He should then note the position on the ground of the next contours obtained from the map. If the slope is uniform the distance between the contours can be divided by form-lines without difficulty. If it is not uniform the approximate place where the slope changes should be marked on the sketch, the steeper portion of the slopes being shown by placing the form-lines closer together, the gentler slopes by placing them wider apart, as described in Chapter V, §15, and Chapter XIV, §54.

The position of watercourses should next be carefully noted and marked in. The position of underfeatures or knolls not shown on the map can usually be fixed either by reference to some neighbouring point marked on the map or by intersection; their approximate height can then be estimated by reference to the position on the ground of some neighbouring contour marked on the map. When the form-lines on the principal spurs and watercourses have been marked in and the position of underfeatures has been fixed, the sketcher will have little difficulty in joining up the form-lines so as to show the shape of the ground. Form-lines should be numbered when first marked in, so as to ensure that they are correctly joined up.

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Chapter XX.

THE USE OF AEROPLANE PHOTOGRAPHS.

§72. Introductory.

257. *Importance in War.*—Owing to the outstanding importance of air photographs in war, it is eminently desirable that all officers should have some acquaintance with them and with their limitations for the purpose of map making; hence the introduction of the subject into this revision of the Manual.

258. *Uses of Air Photographs.*—The use of air photographs for military purposes may be considered under three heads:—

(1) To obtain information. This may be topographical or other information; but if the former, what is meant is information as to the nature of topography as distinct from precise information as to position.

(2) To add detail to a map, or to fix the positions of extra points.

(3) To make an accurate map.

It is evident that (3) is an extension of (2), but whereas to make an accurate map from air photographs requires expert knowledge and as a rule somewhat elaborate methods, it is possible, with proper precautions, for anyone to fix the positions of certain points from air photographs with reasonable accuracy.

259. *Limitation in this Manual.*—It must be understood that to make an accurate large-scale map from air photographs—that is, a map to suit modern artillery requirements—is the work of the expert. Air photographs are subject to certain errors which are usually extremely difficult to detect. They are due to a variety of causes, the chief of which are: (1) oblique, that is, non-vertical, pointing of the camera, and (2) inequalities of the ground. It is reasonable to hope that with improvements in methods it will be possible by simple means to get fully rid of the former cause of error, but at present it is found in most photographs. It is, of course, impossible to prevent the inequalities of the ground from showing themselves on the photograph displaced from their true positions, as is evident from Fig. 60, Art. 266.

It is therefore necessary to enter the caution that, however accurate an air photograph may *appear*, it does not follow that it represents the true plan of the ground. It may give you all the information required for a particular purpose; it will probably provide ample plan material for a good map for infantry work; and it will almost certainly be better than any military sketch, except in the representation of ground forms. But it cannot be

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used for making the highest class of artillery map until it has been tested, and if necessary rectified, by the expert.

The method of dealing with air photographs for this accurate map work is beyond the province of this Manual. All that is necessary here is to explain the rudiments of photo interpretation, in order to assist the beginner to understand air photographs, and to give some simple methods of fixing the positions of points in relation to features already mapped.

§73. Nature and Interpretation.

260. *Two Categories of Air Photographs.*—Air photographs, as at present taken, may be divided into two categories: Vertical photographs and "Obliques." The former are taken with the optical axis of the camera held as nearly vertical as possible, while the latter, as their name implies, are taken with the optical axis inclined obliquely to the ground.

261. *Vertical Photographs.*—Vertical photographs present in themselves a picture closely analogous to a map, but differing in certain important particulars, the principal of which are:—

(i) Every photograph requires more or less "interpretation"; that is to say, objects photographed from above in this way cannot always be recognized by persons who are accustomed to their appearance seen from the ground.

(ii) The photograph carries no indication of scale.

(iii) No names or descriptive matter appear.

(iv) It gives little or no indication of contours and heights.

(v) It is not at present possible to ensure that every photograph is taken on a true vertical; and when this is not the case the print will show a distortion or perspective effect, often by no means easy to detect, due to the fact that the plate and the ground were not parallel at the moment of exposure. The scale of the photograph is not therefore uniform all over.

262. *Oblique Photographs.*—Oblique photographs are generally taken from a low altitude, 500 to 1,000 feet, and yield a picture analogous to a panorama photograph taken from a commanding ground station. They have not yet been of much direct value for mapping purposes, but are often exceedingly useful for assisting in the "interpretation" of vertical photographs, and for supplementing the ordinary sketched or photographed panorama, particularly in flat country.

263. *Interpretation.*—The complete interpretation of all varieties of photographs calls for a high degree of skill, imagination, and experience, and must be regarded as "specialist" work, requiring much study and practice. The ordinary individual

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cannot hope after a few hours' study to detect concealed machine-gun emplacements, battery positions and the like, on a photograph of the enemy's lines.

Certain rules, however, can be given which will at least enable the novice to identify correctly the main topographical features, distinguish cuttings from embankments, roads from canals, and so on.

264. *Identification of Features.*—As a general rule objects on a photograph are of two kinds :—

(*a*) Those features such as roads, railways, canals, which lie on the surface of the ground only.

(*b*) Features such as trees, buildings, chimneys, churches, which stand up above ground.

(*a*) The former can generally be identified at once, even by the novice, particularly if a map is available to refer to.

Railways are distinguished by long straight lines and regular curves and by the presence of stations, rolling stock, &c., at intervals along their length.

Roads and tracks are commonly rendered prominent by their light colours.

Canals are usually distinguishable from streams by their more uniform width and generally straighter appearance.

265. *Shadows.*—(*b*) Objects which stand up above the ground are generally best identified by the shadows thrown by them, and are as a rule more difficult to detect. For this reason an examination of a photograph should invariably be commenced by noticing the direction of the light on the ground. This is given by the shadows of trees, which are unmistakable.

Consideration of the direction and position of shadows will then at once enable raised objects to be distinguished from those sunk on the ground. Cuttings, for example, can generally be distinguished from embankments in this way and mounds from pits.

Many objects such as factory chimneys and church spires, which are most conspicuous to an observer on the ground, are most difficult to pick out on a vertical photograph. The shadow thrown by a tall chimney or a wireless mast is a narrow line which may easily escape notice. Such shadows should be looked for and traced to their origin, which may then perhaps be identified as a small dot.

When, owing to the fact that the sun was obscured when the photograph was taken, shadows are ill-defined or non-existent, or where such cast shadows are confused with other detail, as is often the case when, for example, the shadow of a tall chimney falls across other buildings, it may be impossible to discover either the shadow or its cause. For this reason oblique photographs which do not depend on shadows for their interpretation are very useful. Church spires, windmills, and wireless masts,

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&c., are unmistakable on such a photograph, and a comparison of a vertical photograph with an oblique of the same area will generally enable all important points to be correctly identified.

§74. Methods of Plotting from Photographs.

266. *Fixing Positions from Air Photographs.*—When there is a fair amount of detail on the photograph which is represented on the map—presumed accurate—there should be no difficulty in fixing the position of a required point with sufficient accuracy for most purposes. The surrounding detail, prolongations of lines made by joining known points, allowance for the difference of scale between the photograph and the map, together with the exercise of topographical knowledge and common sense, should enable a fixing to be made with little error.

When little or no detail exists, it is less easy. It is evident that, in order to fix the position of an unknown point, it must be possible to identify on the map, and thus know the position of, a certain number of points on the photograph. This is an elementary requirement in any survey or mapping: to fix a new point you must know some previously fixed points. In a photograph it is necessary to have at least four fixed points. With these the positions of a number of others can be determined.

It must first be stated that the methods given below depend for their accuracy on the known and unknown points being on approximately the same level. If there are differences of level there will be a resulting error in the position of the unknown point, which may or may not be serious according to circumstances. (Compare Fig. 60.) Small differences of level do not matter much; and any differences of level are much less important when the photograph is taken on a true vertical.

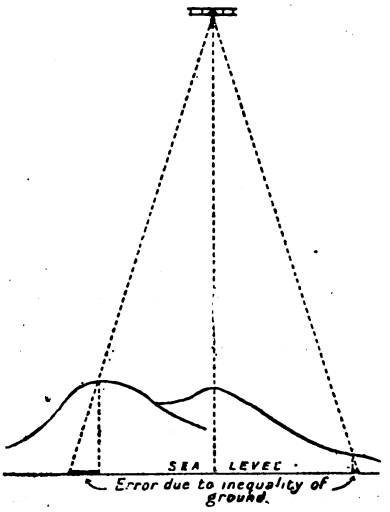

FIG. 60.

As already stated, it is often impossible to tell from inspection whether a photograph was taken vertically or not; but it should be noted that even in the case of a true oblique photograph (Art. 262), the following methods are quite practicable if the points, known and unknown, are on a level, but result in serious errors if they are not.

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The first of these methods (Perspective Plotting) is suitable for sketching in detail on a map; the second (Four-point method) is useful for fixing the positions of single points accurately.

267. *Perspective Plotting.*—Let A, B, C, D (Fig. 61) be four fixed points on a photograph and A′,B′,C′,D′ the same points on the map. Join these points in each figure, forming the sides and diagonals of quadrilaterals. Produce the converging sides in both figures to meet in E, F; E′, F′. Draw from these points lines to the intersections of the diagonals to cut the two opposite sides of the quadrilaterals. This subdivides each quadrilateral into four corresponding smaller quadrilaterals, whose second diagonals are ruled in. The crossings of these lesser diagonals are again joined to the external intersections of the complete quadrilaterals, and the process continued until finally both photograph and map

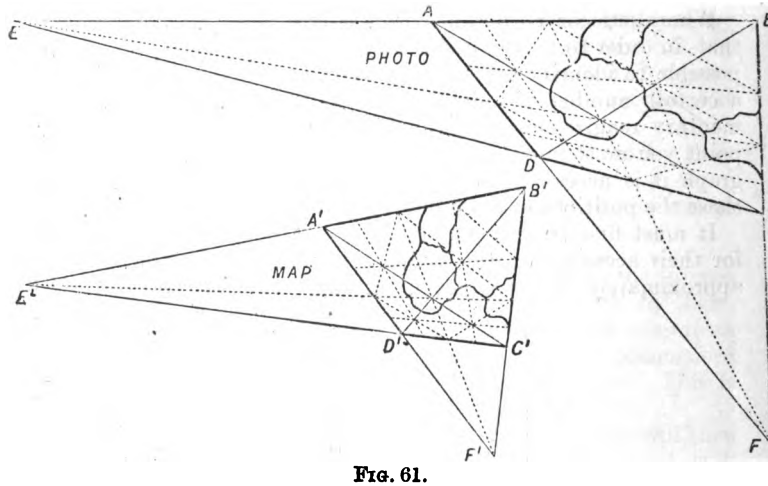

FIG. 61.

are covered with a network of lines joining points which correctly correspond to one another. When this network is sufficiently small, it is easy to sketch in on the map all the intervening detail on the photograph by its relation to the corresponding lines of the net.

In applying this method, it will usually be necessary to mount the photograph on a sheet of paper.

If five fixed points are available, plotting may be done in a similar way, without using the external intersections, by simply drawing from each point a line to the intersection of the diagonals of the quadrilateral formed by the other four points. The intersections of each line with the sides of the quadrilateral give two new points, to be used for forming new quadrilaterals to the extent required.

The perspective method is useful in dealing with considerably tilted and distorted photographs. Tilted photographs are, however, objectionable for plotting by this or any simple method, for the

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reason that, as stated above, differences of level on the ground introduce large errors; they can be used with safety in none but flat country.

268. *Four-point Method.*—Let A, B, C, D be four points on the photograph, corresponding to fixed points A′, B′, C′, D′ on the map. If possible, they should form a suitable quadrilateral and should not be grouped too close together. Let X be on the photograph, Fig. 62(*a*), an unknown point on the map, Fig. 62(*b*).

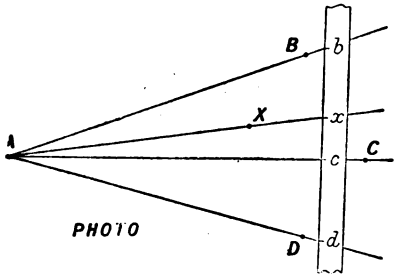

FIG. 62(*a*).

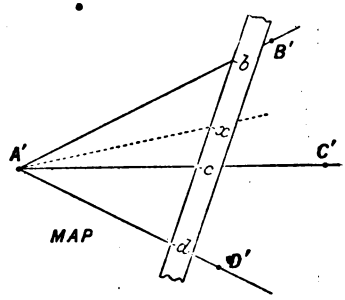

FIG. 62(*b*).

From any one of the fixed points, say A, draw lines through B, C, D and X on the photograph, and in the same way draw lines from A′ through B′, C′, D′ on the map.

Take a slip of paper with a straight edge; lay it anywhere across the lines A B, A C, &c., on the photograph, and tick off each of the points *b*, *x*, *c*, *d*, where each of the rays cuts the straight edge.

Then lay the slip across the corresponding lines on the map and move it about until the lines A′B′, A′C′, A′D′ cut the edge at the points *b*, *c*, *d*. Mark on the map the position of the tick *x*, and draw the line A′*x*, which will pass through the true position of X on the map.

Repeat the process using another point, say B, as the apex or pole, which will also give a ray B′*x*′ passing through the map position of X.

Then X′ on the map, marked by the intersection of the rays A′*x* and B′*x*′, is the true position of the point X which appears on the photograph.

By using a third apex a confirming ray should be drawn; this must also pass through X′, thus controlling the accuracy of the plotting.

When it is desired to plot a number of points from a photograph, instead of one only, this method can be extended and amplified in various ways which result in a certain saving of time. For example, the strip referred to above may be replaced by a scale on which are noted the scale readings of the rays to all the points to be plotted.

The four-point method is of particular value for plotting with accuracy a limited number of important points. If officers are

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called on to place on their maps battery and machine-gun positions, pill-boxes, blockhouses, Datum points, observation posts and so forth, indicated on aeroplane photographs, they will find this method most generally useful.

269. *The Camera Lucida.*—The only optical instrument likely to be used in connection with air photographs, by those who are not specialists, is the Camera Lucida. This is a simple instrument and may be briefly described.

The instrument consists essentially of a small prism or reflector by means of which it is possible to look at a map and at the same time to see superimposed on the map a reflected image of the corresponding photograph. The operator looks downward along a line passing through or very close to the edge of the prism, thus viewing the map directly ; simultaneously he sees through the prism the photograph reflected from the oblique face of the glass. He can then draw any detail he requires.

In the form used during the war the prism was carried on a movable arm, which was clamped to the edge of a table. Below it the map was fixed, and in a suitable position near-by the photograph was mounted on a movable and adjustable easel.

This design had certain defects, and an improved form has now been made in which the prism on its arm is clamped to the easel ; this makes adjustment easier.

The prism has to be adjusted so that its distance from the photograph and the map is proportional to the respective scales of the two, these scales being rarely the same. The positions of the photograph and map must also be regulated so that the detail corresponds, which usually involves a tilting of the photograph in order to correct distortion.

The Camera Lucida requires some practice to use with success, and many find its employment very difficult. It is apt to strain the eye and, although lenses are supplied to provide for difference of scale between the photograph and the map, it is for most people a trying instrument to use if that difference is great.

On the other hand, for those who acquire skill in its use, it is a valuable instrument, as it enables fresh detail to be plotted quickly and accurately.

§75. General Remarks.

270. *Failings of Detail.*—In order to use air photographs properly their limitations must be borne in mind as well as their advantages.

While air photographs give excellent information in certain respects, they fail entirely in others. Perhaps their chief weakness is that vertical photographs give little or no information about ground forms, except to a limited extent to the expert. Apart from this they have other weak points. Lack of names, doubtful scale and unknown distortions have been mentioned. In interpreting air photographs it is quite possible, even for those with experience, to make serious errors.

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For example, hedges cannot always be distinguished from ditches, nor huts and cottages from haystacks; while the possibility of such important features as church spires, chimneys and windmills escaping notice has already been pointed out. Many other features, such as wells, ferries, paths through woods, &c., may not be visible on a photograph at all; while in such important matters as classification of roads, depths of cuttings, and so on, an air photograph is quite unreliable.

These considerations prove that, while an air photograph is a great aid, it can never provide a completely satisfactory substitute for a visit to the ground.

271. *Incomplete Evidence of Relief.*—With regard to relief, with observation and practice certain information can be obtained from air photographs in favourable cases. In hilly country, for example, where slopes are fairly steep, air photographs often give useful information as to ground forms, though heights cannot easily be deduced from them. Study of the shadows thrown by hills, of lines of stratification, and of watercourses, will often give valuable information; and evidence can be obtained from tillage lines in cultivated country, the shapes of fields on hill sides, the windings of roads, tracks, railways, and the lie of canals.

Lastly, if two adjoining and overlapping photographs are viewed through a stereoscope, the relief of features common to both photographs is seen as a rule much exaggerated, and from such stereos a skilled draughtsman can often draw form-lines without difficulty.

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Chapter XXI.

APPROXIMATE METHODS OF FINDING TRUE NORTH AND NIGHT MARCHING BY COMPASS.

§76. True North by Watch.

272. Some knowledge of the simple elements of astronomy—that is, of the movements of the heavenly bodies—is a most useful asset to the officer or soldier, and is not difficult to acquire. The methods which are given below of finding the cardinal points do not, however, presume any knowledge of astronomy. Every soldier should be familiar with them, for they may prove invaluable in the execution of a sketch or the conduct of a march, as well as on occasions with which this Manual is not concerned.

273. *By Watch.*—Lay the watch flat, with the hour hand pointing to the sun. The direction of true south is then midway between the hour hand and XII in the northern hemisphere. In the southern hemisphere point XII to the sun; then true north lies midway between XII and the hour hand.

Thus, in northern hemisphere, time 15 hours (3 p.m.). With watch set as described above, south lies in the direction of 13½ hours (1.30 p.m.) and north in the opposite direction.

This method is very rough. It is of no use in the tropics. The further away from the equator the more accurate it becomes. Replacing the watch by a 24-hour dial drawn on the sketch does not make for much greater accuracy in the absence of a special device.

§77. True North by Compass.

274. *Reduction of Magnetic to True North.*—True north may easily be obtained from magnetic north if the variation of compass is known. Thus, if the bearing of an object in the field as given by compass is 37° in a neighbourhood where the magnetic variation is 15° W., the true bearing of the object is 22°. The object being shown on a sketch, draw a line to it from the position of the observer and from this line plot 22° backwards (*i.e.*, contra-clockwise): the direction so drawn is that of true north.

If one is sketching in the field *and the sketch is set*, it is not necessary to observe an object, provided the axis of the compass is sufficiently defined, as by the notches in the service prismatic pattern. In this case open out the compass, lay it flat on the board, and turn it until the card reads the degrees of variation if the variation is West, or 360° *minus* the variation if the latter is East; then mark the drawing at the notches and draw the true north and south line through the points thus pencilled.

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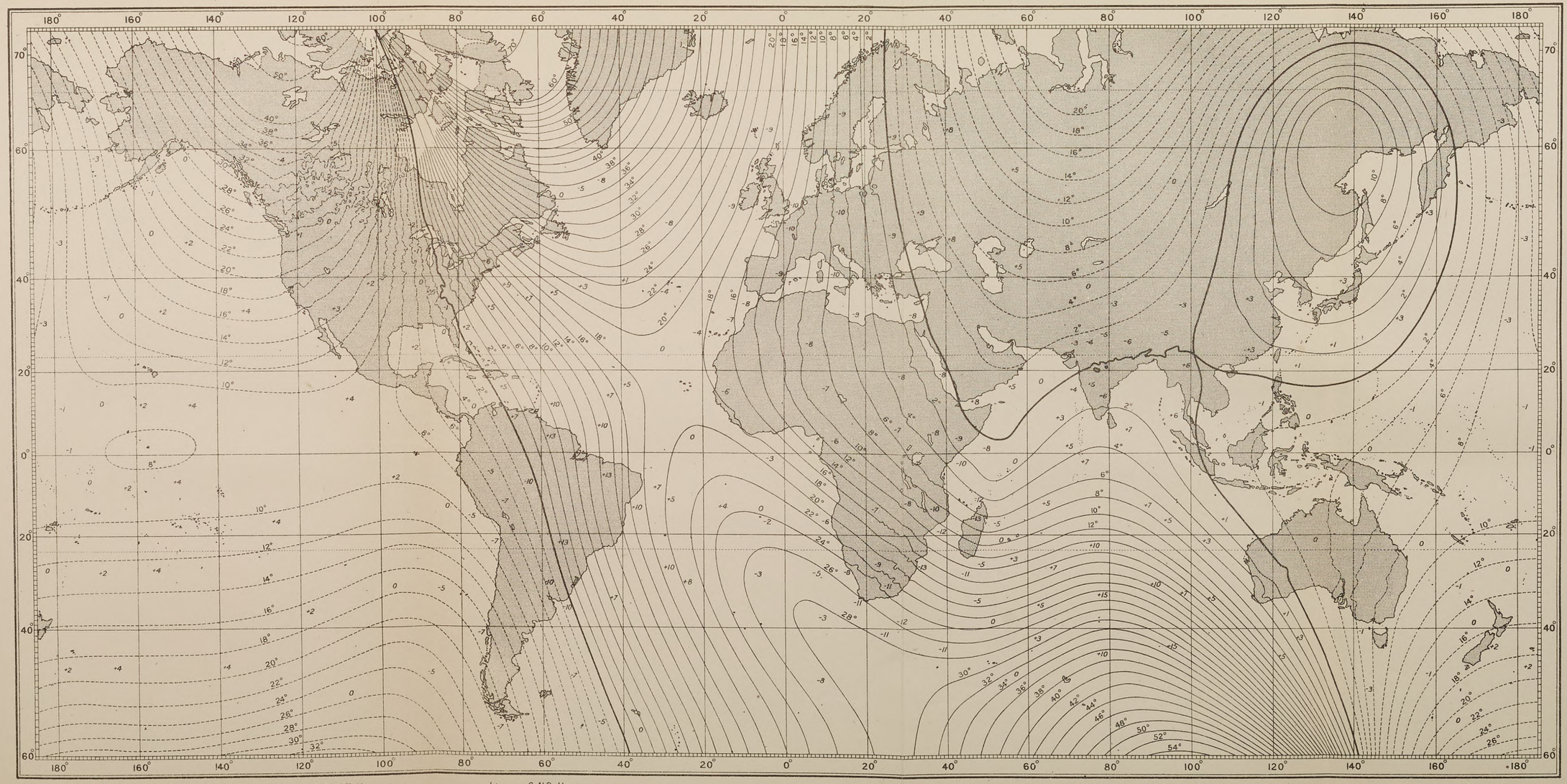
CURVES OF EQUAL MAGNETIC VARIATION (ISOGONALS), 1920.

Showing also approximate Annual Changes in Minutes of Arc.

Plate XXIV



Lines of WEST Variation ——— *Lines of EAST Variation* - - - - - *Lines of NO Variation* ———

0 Indicates NO Annual CHANGE *+ Indicates Annual INCREASE* *- Indicates Annual DECREASE*

Truscotts, London.

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275. *Resolving Doubts.*—If there is any doubt as to whether true or magnetic bearings are the greater, draw a rough diagram. Thus, from Fig. 63 (*a*), showing variation West, it is clear that the

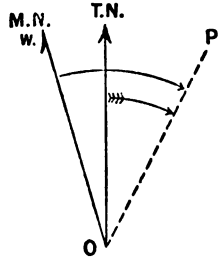

Fig. 63(*a*).

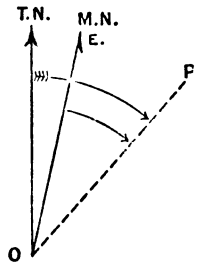

Fig. 63(*b*).

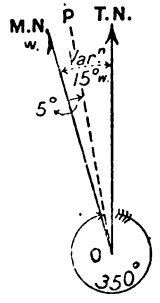

Fig. 63(*c*).

magnetic bearing is the greater; while from Fig. 63 (*b*) showing variation East, it is evident that the true bearing is the greater.

Remember always that the difference between the true and magnetic bearing is the amount of the variation. In Fig. 63 (*c*), for example, the rule still remains true, for the magnetic bearing is 5° (*i.e.*, 365°) as compared with a true bearing of 350°.

276. *Magnetic Variation* does not remain constant. For instance, it has different values in different parts of the world. Plate XXIV shows its value for 1920 over the world. Further, it changes from year to year. At present the westerly variation in the British Isles is decreasing by from 9½ to 10 minutes annually. Plate XXIV gives the approximate "Annual Change" in different parts of the world, and from these figures the value of the variation for future dates may be deduced.

It should be noted that maps and charts like Plate XXIV can give only the mean variation in a locality. Moreover, every ordinary compass has its individual variation, which may differ from the mean. Compass users should not rely too much on the charted variation, but should test their compasses on lines of known true bearing, say, between trig. points; and this should be done periodically. Bearings taken from a small-scale map by a small protractor are barely good enough for this purpose; a good circular protractor and well-drawn map like the 1/20,000, showing the graticule, would be necessary.

You must bear also in mind that your line of known bearing may not be free from magnetic disturbance; hence comparisons at both extremities are desirable, and if you can compare on two different lines so much the better. (*Cf.* Chapter xv., § 57.)

§ 78. True North by the Sun.

277. *By Equal Altitudes of the Sun.*—Drop some sealing wax on a penny and press down thereon the flat end of a pencil,

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taking care that the latter is truly upright and central on the face of the coin. Place the "style" so formed on a table in the open, to which a square of white paper is pinned. Run a pencil point round the coin and find its centre O, Fig. 64. At about 10 a.m. note that the shadow of the pencil's point is at A. Mark A and join it to O and with O H as radius draw the circle C around O. Note that as the sun moves the shadow at the same time retreats inwards from C.

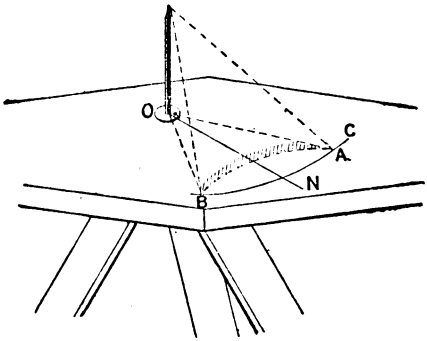

FIG. 64.

At about 13¾ hours examine the shadow again; note that it is again approaching C. At about 14 hours the apex of the shadow again crosses C; mark the point of crossing B. Then O N, which bisects the angle A O B, is the direction of true north in the northern hemisphere or true south in the southern hemisphere.

The reader can improve at will on this crude arrangement, and can experiment on the ground with the shadow of the corner of a roof suitably situated or with a pointed stake set, somewhat leaning, in the ground. The centre of the circle C in these cases is vertically beneath the edge of the roof or the point of the stake; in the latter case it may be obtained by aid of a weighted string or plumb-bob.

If the observer's position be not too near the poles, the apparatus be suitable and care be taken with the working, it is possible to obtain true north with considerable accuracy by this method.

§79. True North by the Stars.

278. *Northern Hemisphere—The Pole Star (Polaris).*—Everyone should be familiar with the Pole Star. It is the bright star indicated by the two "Pointers" of the Great Bear or Plough, Fig. 65.

Polaris gives an approximate line to true north. In latitudes less than 60° it is never more than 2¼° in bearing from the Pole. All stars revolve round the Pole and twice in the 24 hours Polaris is in the meridian, *i.e.*, truly north. Midway between the times when it crosses the meridian, Polaris is approximately at its extreme distance, *i.e.*, 2° about lat. 45°, east or west of true north.

There are two easy ways of knowing when Polaris is in the meridian: the first, by means of stars in the constellation of the

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Great Bear; the second by stars in Cassiopeia, which is a conspicuous group, shaped like the letter W (Fig. 65) on the opposite side of the Pole Star from the Great Bear.

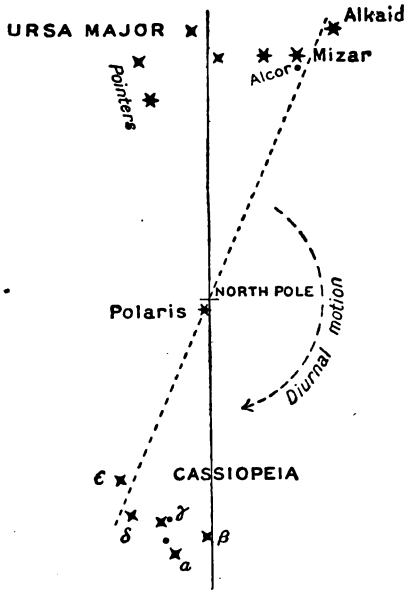

FIG. 65.

The Pole Star is exactly north when the point half-way between the two end stars of the tail of the Great Bear is vertically above or below it; and the same is true for the point half-way between the two stars which form the first stroke in the W of Cassiopeia. Note this line of points, as pecked in Fig. 65, passing through Polaris.

It may be mentioned that while this rule is for practical purposes true at present, the points mentioned gradually change; in the first case toward the last star (Alkaid) of the Bear, through which the line will pass about 1948; in the second case toward the first star of the W, which the line will reach about 1960. By those dates, therefore, the Pole Star will be in the meridian when the stars mentioned are exactly above or below it.

As the height of the Pole, in other words the latitude, increases, Polaris becomes of increasingly less value as a means of finding true north.

279. *Southern Hemisphere—The Southern Cross.*—The Southern Cross may be used as follows: Consider the Cross as a kite; prolong the greater axis $4\frac{1}{2}$ times in the direction of the tail, and the point reached will be approximately the South Pole. If a piece of paper be marked off along its edge by 12 dividing lines, spaced equally, and be held so that the first and third scale lines coincide with the head and tail stars respectively, the intersection of the 12th line with the edge of the paper will give approximately the southern Pole.

The southern Pole is more difficult to fix than the northern, as there is no bright star near it.

280. *Southern Cross and Hydrus.*—Continue the line above described for another two lengths of the greater axis of the Cross, *i.e.*, to the 16th line of the scale; we thus reach a star named β Hydri, which of the bright stars is the nearest to the South Pole.

Now when α Crucis, in the tail of the kite, and β Hydri are in the same vertical, they are nearly in the meridian and thus mark true south.

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§80. Night Marching.

281. Night marching under the best conditions of direction is an operation demanding lengthened practice and the greatest care on the part of the guide. Unless the guide has a knowledge of elementary astronomy and possesses tables to give him the correct bearing of the stars, the direction of a night march in a country unknown and unmapped or featureless must be maintained by compass, luminous for dark nights.

282. *Marching on a Compass Bearing.*—The guide must know the bearing on which he wishes to march. He then observes some object which has the required bearing and marches towards it.

In the Service Prismatic Compass the magnetic north is marked by a broad luminous arrow-head. The glass cover is turned until the setting-vane on its rim, corresponding to the luminous direction mark on its glass, points to the required magnetic bearing as shown on the external ring; the cover is then clamped at this bearing. The box is now held so that the direction mark is superposed on the arrow-head, in which position the line of the luminous patches in the lid, fully extended, indicates the line of advance.

In the liquid type of compass the bearing may be read directly at night with the same exactitude as by day; but in night marching some of this accuracy is unavoidably lost and marching on the indexes is in general sufficient.

As a rule, the darker the night the greater the assistance afforded by the luminous paint. During a moonlight night a luminous compass may be of no greater value than an ordinary compass with a clearly marked north point.

283. *Prolonging the Compass Indication.*—In using a compass during a night march, means may have to be adopted to prolong the line of advance as shown by the compass, and thus clearly indicate the route to be followed. A stick painted white or with white paper pasted on it, or, best of all, one prepared with luminous paint is most useful. The operator, standing perfectly steady, should wait until his compass has come to rest, and then hold the stick, at an angle of 45° to 60° with the horizontal plane, in the direction indicated by the line between the luminous patches in the compass-lid.

With the stick thus held it is easy, except on very dark nights, to pick up some object on which to march; the advance is continued until the guide considers it desirable to halt and allow the compass to settle so as to observe the direction of advance afresh.

The object may be terrestrial or it may be a star. If it is terrestrial the march can be continued until the object is reached, when a new point must be chosen. If the object is a star, it must be remembered that the bearing of a star, except one close to the Pole like Polaris, is constantly changing. An advance can be

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continued on a star for 10, 15 or 20 minutes according to its position in the heavens.

284. *Celestial Objects.*—The most convenient stars to select for marching on are those which happen at the time to have an altitude of from 15° to 30°; stars below 15° may become lost in haze, whilst for those above 30° the head has to be inconveniently raised. Speaking broadly, a star at these altitudes will rarely move more than 5° in azimuth (*i.e.*, to a flank) in 20 minutes. Hence if at the end of every 15 or 20 minutes the observer halts and takes a fresh bearing, he can count on keeping direction correctly.

Although it is of assistance to an observer to know the stars, it is not *necessary* that he should know them. Anyone can, with care, march on a compass bearing with the stars as points to direct him, with satisfactory results, although he may be totally ignorant of the names of the stars or even of the constellations. The great point is to be sure that the compass bearing is correctly taken and prolonged, and that the star selected is adhered to until a change is required.

In civilized and well-mapped countries the use of stars for keeping direction is not likely to be necessary. In uncivilized country, on the other hand, the method may be of great value. Any officer to whom such a task would be likely to fall would be wise to acquire an elementary knowledge of astronomy, so as to know how to march even when no compass is available.

285. *Marching by Compass when no Objects are Visible.*—It may happen that, owing to clouds or fog, no terrestrial objects to march on between the halts are visible; then the only safe way is for an assistant to stand behind the observer and work as follows:—The guide with the compass and luminous stick, as soon as the compass becomes steady, gives the word "steady." The assistant, carefully noting the alignment of the luminous stick, then advances in what he judges to be the right direction, until the guide halts him, before he is lost to sight, by giving a low whistle.

The guide, having thus halted his assistant, notes by means of the compass whether the latter is standing on the true line of advance or to the right or left of it. He then moves up, and placing himself on what he judges to be the correct alignment, sends forward his assistant again.

The rate of advance obviously depends on the distances covered between halts; after the first few advances the assistant will have ascertained the number of paces he can safely proceed without being lost to sight, and on reaching that distance he will halt without waiting for the whistle. This is important, since the whistling might give notice to the enemy as the force approaches the objective.

Slabs of cardboard or wood, prepared with luminous paint, are of great assistance in this tedious process of sending on an assistant; a slab. 12 inches square, can be seen at from 30 to 200 yards

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distance, according to the condition of the atmosphere and the paint, and by this means the rate of advance can be greatly accelerated.

Besides the guide and his assistant, a third person should be employed to keep a careful record of the distances traversed.

It may be useful to remember that a constant error of 5° in bearing causes a deviation from the course of 150 yards per mile of march.

The student may consult:

The Stars as Guides for Night Marching in Lat. 50°. By E. WALTER MAUNDER, F.R.A.S. London: Chas. H. Kelly, 1916.

Rapid Night Marching Made Easy. By Major W. A. TILNEY. London: Hugh Rees, Ltd., 1909.

The Star Pocket Book. By R. WEATHERHEAD. London: Longmans, Green & Co. 2nd Ed., 1915.

Steering by the Stars. By JAMES DUNDAS WHITE, LL.D. London: J. D. Potter, 1916.

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Chapter XXII.

MILITARY RECONNAISSANCE.

§81. Introduction.

286. *Necessity for Report.*—Reconnaissance of the ground is a practically indispensable preliminary to any military operation, whatever its scale or nature. Whenever possible, such reconnaissance will be made by the commander who has to conduct the operation; but it will sometimes occur that it is impossible for him to make a personal reconnaissance, and the larger the scope of the operation the more certain is it that the commander will not be able to make more than a cursory inspection of the ground, sufficient to furnish a broad basis for the outline of his plan. He is then compelled to have recourse to the employment of subordinate officers to obtain for him the detailed information necessary for the elaboration of the plan. Such information will be presented to him in the form of a report.

287. *Verbal and Written Reports.*—Reports may be rendered verbally or in writing. Whenever the circumstances permit, they should be written. A written report has the advantages that it furnishes a permanent record of the information it contains, that it minimizes the risk of misunderstanding, that the information furnished can be more easily distributed to the branches of the staff and the departments to whom the several items are of interest, that it is easier to arrange the matter in a logical and convenient form, and finally that there is little risk of omitting useful information when the officer furnishing the report sits down deliberately to commit it to writing.

The principles governing the information to be furnished and the form in which to present it are the same in both verbal and written reports. Practice in preparing the latter is thus the best training for rendering the former. This chapter will, therefore, be confined to the consideration of written reports.

§82. Nature and Preparation of Report.

288. The preparation of a report involves the consideration of two questions:—

(i) What to report. (Matter.)

(ii) How to report it. (Form.)

(i) *Matter.*

The answer to the first question above is: Everything of value for the purpose for which the reconnaissance is ordered. This

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implies that a report should always be prepared with a definite purpose in view and every item of information must be examined and either included or rejected by the light of its relevance to that purpose.

Hence it follows that the first step to be taken by an officer ordered to carry out a reconnaissance is to get thoroughly fixed in his mind the *purpose* for which his report is required. If this is not clear to him from his instructions he should, if possible, ask for an amplification of the points on which he is not clear. In exceptional cases, when such amplification is not obtainable, it is legitimate to make assumptions; any assumption so made should be clearly stated at the beginning of the report.

289. *Alternative Solutions.*—When the problem admits of more than one solution the reconnoitring officer must not assume, unless his instructions definitely state the fact, that the commander will adopt that solution which he himself regards as the most favourable. Considerations unknown to him may turn the scale in favour of the apparently inferior solution. It may be admissible for the reporting officer to make a recommendation, in which case the recommendation must be supported by a logical and reasoned statement of the considerations on which it is based; but the report must supply data relevant to all practical alternatives. The decision as to the course to be adopted rests with the commander, and that decision cannot be properly based without full knowledge of the main facts; the details are required by his staff for carrying into effect the plan he may adopt.

290. *Headings of Information.*—The second step for a reconnoitring officer is to imagine himself in the position first of the commander requesting the report and, secondly, of the members of the staff. He should then ask himself the question: If I had to decide on this case and to carry my decision into effect, what information should I require to supplement that on the map in my possession?

At this stage he should note on paper certain headings on which he decides that further information is desirable, and also any questions which appear to demand answers on the ground. Reasonable time spent on this before commencing work on the ground is not wasted. In the field it will save loss of time spent in running after and recording irrelevant detail, will shorten work by ensuring a methodical tackling of the problem, and will in great measure guard against the danger of overlooking essential or useful features of the position.

291. *Influence of Time.*—In answering the question "What to report" it has been stated above that this should comprise everything of value for the purpose for which the reconnaissance is ordered. It is now necessary to qualify this statement. Time is more often than not a controlling factor. The commander who orders a reconnaissance generally specifies that the results shall

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reach him by a certain time. It is more important that the information obtained should arrive in time to be of use than that the report should be long and elaborate. (F.S.R., Vol. II, 68, 4.) When, as will often happen, the time available for the execution of the reconnaissance and the preparation of the report does not permit of the inclusion of all information bearing on the problem, the reconnoitring officer will be faced with the necessity of deciding ruthlessly what to include and what to omit.

Generally speaking, minor detail, of interest to subordinates only in the execution of their part in the operation, must in such cases, be sacrificed to vital factors such as would influence the decision as to the course to be adopted and would control the formulation of a plan for carrying out the operation. Much time will be lost in looking out for and recording unessential detail unless the reconnoitring officer makes up his mind beforehand as to essential features and sets out to look for these alone, and unless he has in addition the quick eye for country which comes only of practice in reconnaissance and sound military judgment.

(ii) *Form.*

292. *Avoidance of Formality.*—Of only slightly less importance than the matter contained in a reconnaissance report is the form in which that matter is presented.

The use of typical forms of report and stereotyped lists of headings is to be avoided. No two problems are exactly similar and such forms and lists of headings cannot be designed to cover every case of even one class of operation. Their use tends to militate against the intelligent treatment of each problem on its own merits, as outlined in the preceding Articles. Accordingly, the suggestions which are given later as to the kind of information to be furnished and the manner of classifying it are to be taken merely as a general guide, the purpose of which is to assist officers in preparing their own list of queries for their individual problem and in making a logical arrangement of the matter in their reports, so that it may be in a form most conveniently accessible to those who have to see to its application.

293. *The Value of a Map or Sketch.*—A map or sketch is a graphical presentation, by the use of conventional signs, of certain information regarding the area represented. On it can be recorded—

(*a*) The existence of certain features, natural or artificial;

(*b*) Their positions relative to one another;

(*c*) Certain facts regarding them, *e.g.*, the forms of hill features, the extent and outline of woods, the shape of buildings, the course of streams.

To anyone accustomed to the use of maps there is no better way of communicating such information than by this means. From no verbal or written report can the recipient form a mental

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picture of the ground so rapidly or so accurately. A map of some kind is therefore essential to a reconnaissance report; in fact it would perhaps be more correct to regard a report as an adjunct to the map or sketch than the converse. A report without a map for reference is of little or no practical value; whereas, by supplementing the information which can be conveyed through conventional signs by the addition of a few written notes on the face of the map it may often be possible to dispense with the separate report.

294. *The Necessity for a Sketch-Map.*—If no map of the area to be reconnoitred exists, the first task of the officer will be to make one, however rough. The methods by which this can be done are dealt with elsewhere in this Manual (Chaps. XIV, XV, XVI, XVII), and no further reference to them is necessary here, though many of the remarks which follow apply with equal force to sketches so made.

As a rule some sort of map will be available, usually of small scale. The scale imposes a limitation on the amount of information that can be shown (*cf.* Fig. 3). Much that would be useful has to be excluded in order that detail may be legible. As the map has probably been prepared to serve a variety of purposes and may not even have been made with a view to its use for military operations, detail which may be of vital military importance may have been subordinated or even sacrificed to make room for the inclusion of information of utility for other purposes. Information which cannot without undue complication be shown by conventional signs has generally to be omitted from a small-scale map, largely because of the small space available for printed description.

Moreover, the map may be inaccurate; and, even if this is not the case, certain details of military importance are liable to constant variation, *e.g.*, state of roads, passability of the ground, amount of cover afforded by crops, woods and hedges, field of view, extent of obstacle presented by streams. For these and other reasons it is frequently of value, even when a good map is available, to make a special sketch-map to illustrate the report. When the existing map is of small scale, say, $\frac{1}{4}$, $\frac{1}{2}$ or 1 in. to a mile, this sketch-map should be prepared on an enlarged scale.

295. *Influence of Scale.*—A sketch-map to illustrate a report is of no value unless it either—

(1) Supplements the information given on any map already available;

(2) Corrects inaccurate information on such map;

(3) Emphasizes, without undue exaggeration or loss of accuracy, information which has an essential bearing on the particular problem.

There is no inherent merit in a large-scale map over one of smaller scale except the possibility of showing more information or of making that shown more legible.

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296. *Preliminary Reconnaissance.*—Assuming that a small-scale map is available and that he has decided in favour of making a sketch-map on a larger scale, the first step of the reconnoitring officer is to study carefully, with the aid of the small-scale map, the military problem and to make up his mind generally upon the features demanding more detailed treatment. If time allows, the decision can be better reached by a hasty preliminary reconnaissance, the officer cycling or riding rapidly over the ground to get a general idea of the problem, without pausing to make notes. It is better still—and an indispensable first step when the country is favourable—to visit one or more high points from which, with the aid of field glasses, a general idea of the ground as it affects the problem can be obtained; for such a view affords all the information necessary for the purpose at a minimum expenditure of time.

297. *Enlarging and Adding to the Map.*—At this stage, if he has not already done so, the officer should sit down and rapidly enlarge to the requisite scale the necessary portion of the small-scale map. Many sketchers prefer to execute the enlargement before going out; there is no objection to this if the exact area to be covered is known beyond doubt before the ground is visited.

Provision is made in war establishments for survey units which are provided with complete equipment for mechanical enlargement by photographic methods. Occasions may arise when it will be advisable to take advantage of the existence of these units.

Having made up his mind, after the preliminary reconnaissance, as to the parts of the area for which he wants further information, the sketcher now proceeds to these points or to others from which he can command a good view of them, and fills in the needful detail, at the same time making any useful notes. The manner of working is described in Chapter XIX.

Finally, the sketch is to be finished off, and the report, if any is necessary, written.

298. *Information on Enlargement.*—The enlargement should reproduce all the information on the original map which can have any bearing or influence on the problem. In the interests of greater clearness any detail which can have no such bearing may be omitted, unless required to furnish fixed points by the aid of which important detail can be correctly located and inserted. Great caution must be exercised in the selection of detail to be omitted.

As much relevant detail and information as can be included without making the map difficult to read should be shown either by conventional signs and ordinary mapwork, or in the form of neatly written notes. In many cases when this has been done it may be found that all the information required has been recorded and that a separate written report would be a mere repetition of what is already apparent from a study of the map. Very often, however, it will not be possible, without making the

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map too involved, to dispense altogether with a written report. Sometimes, even when all the data can be recorded on the map, it may be desirable to append a brief written report with the object of presenting conclusions arrived at, or of giving special prominence to certain aspects of the country or to particular considerations which have a direct bearing on the problem.

(iii) *Arrangement of Matter in Report.*

299. Assuming that the reconnoitring officer has decided that a report is necessary, he has to consider the best mode of assembling the observations recorded in his notebook, together with his recollections of the details seen. The report should, obviously, be arranged in that form which will be most convenient for those who have to use it. These are, first the commander for whom the reconnaissance has been undertaken, and secondly the staff officers and subordinates who will be responsible for working out in detail and executing his designs. The former requires only a comprehensive view of the situation, presenting clearly and unencumbered with minor detail those points of which he will have to take account in arriving at his decision. For subordinate officers, on the other hand, greater importance will attach to questions of detail and, since each will have his own sphere of responsibility, it will be convenient and greatly enhance the value of the report if the detailed information is so classified under headings that each staff or subordinate officer will be saved the necessity of searching through the whole mass to pick out the items which concern him.

From this it follows that a logical and convenient arrangement of a report is in two parts. Part I should be written primarily for the use of the commander and should take the form of a general summary of the results of the reconnaissance. Part II should contain detailed information collected under headings, and, where possible, arranged in tabular form. For Part I set headings are to be avoided, though it is possible to indicate for each class of reconnaissance certain points which should invariably receive attention. For Part II headings, usually the same for the same nature of reconnaissance, can be generally justified. The disadvantages in this case of a regular form are counterbalanced by the greater ease with which the report can be analysed and diverse reports collated.

§83. Types of Reconnaissance.

300. *Intention.*—In the succeeding paragraphs certain types of reconnaissance and certain features which are common to several types will be considered; mention will be made of various points in connection with them on which it may be desirable to record information. Unless otherwise expressly stated, these points must not be regarded as forming lists of headings to be adopted as they stand. The intention is only to furnish a beginner

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having to make a reconnaissance with hints as to some of the things he may have to consider, and to protect him, until he becomes more expert, from the risk of overlooking matters which may be of importance. The case of a deliberate peace-time reconnaissance of an area within which it is desired to collect and record the fullest possible detail on all subjects, without regard to any particular military operation, is outside the scope of this book.

(i) *Reconnaissance of Roads.*

301. *Outside Hostile Zones.*—Reconnaissance of roads may be ordered with a view to a variety of purposes; the relative importance of the different considerations will vary enormously according to the object of the reconnaissance. Thus, if it is made with a view to a march remote from the enemy, the comfort of the troops and, therefore, the characteristics of the road as a channel of communication demand first consideration. Such points as the following must be reported :—

(1) Surface condition.
(2) Width, particularly of metalled portion.
(3) Gradients. (Mention such only as are steep enough to affect rate of marching or to present a difficulty to transport.)
(4) Bridges, with a view to the loads they will carry.
(5) Points where special measures for control of traffic may be required, particularly very narrow or winding ways through a town or village.
(6) Watering places, with a statement of the facilities and number of horses that can be watered at a time.
(7) Towns or villages on or near the route, from the point of view of billeting.
(8) Local administration, names and addresses of mayors and chief civil functionaries.
(9) Telegraph and telephone lines and offices.

302. *In the Presence of the Enemy.*—Where the road has to be reconnoitred with a view to a march in the presence of the enemy, or when the possibility of encountering him is not precluded, first importance has to be given to tactical considerations. The character of the country through which the road passes becomes then of more interest than the actual details of the road itself. The point of view from which the country has to be regarded will vary to a certain extent according as the march contemplated is an advance or a retreat.

Part I of the report should deal in general terms with such subjects as :—

(1) The general nature of the country—whether open or enclosed, and the extent to which it favours delaying action by a small mobile force.

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(2) The extent to which the road is under observation and commanded by surrounding features.

(3) Defiles.

(4) Tactical points which must be secured, in the case of an advance, before the main body can pass any particular point; or which, in the case of a retreat, must be held until it is past a certain point.

(5) In the case of an advance, any positions particularly favourable to the enemy for opposing the advance, with a very brief statement of the considerations that constitute the strength of such positions and affect the decision as to the best mode of attack on them.

303. In *Part II*, information may usefully be given on the following in addition :—

(1) Particulars of the roads as for a march under peace conditions. More especially in the case of an advance, greater detail should be given regarding bridges; for example, the possibility of executing temporary repairs and of constructing alternative crossings should receive ample treatment.

(2) Obstacles to deployment from the road.

(3) Obstacles to movement across country, such as woods, swamps, rivers and streams, railway cuttings and embankments, &c.

(4) More detail regarding positions favourable to delaying action by the enemy or opposition by him to an advance. (*See* Reconnaissance of a Position for Attack, Art. 314; but as it is not certain that the enemy will be met in any particular position, detail need not be so full as in the case of a reconnaissance with a definite view to attack.)

(5) In the case of a reconnaissance for a retreat, a more detailed report on positions favourable to rearguard action.

(6) In the case of retreat, points where delay could be caused with little labour but with considerable inconvenience to the enemy, either by demolitions or by blocking the road where movement off it is restricted.

(ii) *Reconnaissance of a River.*

304. A river may be of military importance either as a channel for water-borne traffic or as an obstacle. To report on its capacity as a means of supply is the task of an expert and will not be considered here.

A River as an Obstacle.—The information required in regard to

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a river as an obstacle will vary in character according as it is to be considered :—

(*a*) From the point of view of its general effect in restricting movement.

(*b*) As an adjunct to the defence of a position.

(*c*) As an obstacle to be crossed in the face of resistance.

305. (*a*) *Generally.*—The most material considerations are :—

(1) Average width and depth in different stretches.

(2) Nature of bottom.

(3) Approximate strength of current.

(4) Character of banks.

(5) Existing crossings, nature and dimensions of bridges, loads they will carry, and particularly their practicability for motor transport, heavy guns or tanks. (When in doubt give dimensioned sketches and leave to the expert the calculation of loads.) In the case of fords state depth, nature of approaches, bottom and strength of current. Describe the nature of ferries and the load which the vessel will take.

(6) If some time may elapse before the report is utilized, ascertain by enquiry or observation the effect of heavy rain or a thaw and the liability to flood.

306. (*b*) *In Defence.*—In addition to the points above, report on :—

(1) Tactical considerations affecting the enemy's probable choice of a point of attack, *e.g.*, cover on his side facilitating surprise, sections in which the course of the river or the configuration of the ground on his side favour concentration of fire in support of an attack, any stretches in which the river cannot easily be covered by the fire of the defence.

(2) The defensive position (*see* Reconnaissance of a Position for Defence, Arts. 315–8).

(3) Locks, dams, and weirs and other artificial means of controlling the waters of the river, their influence on water level and the possibility of utilizing them to form inundations.

(4) Existing crossings. These should be reported on from the point of view of possible destruction and the extent to which their destruction would impede the enemy. Details required are the nature of bridge, number and width of spans, nature and dimensions of piers, nature and height of abutments, thickness of arch in a masonry bridge and number and detailed dimensions of girders in a steel bridge.

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307. (*c*) *In Attack.*—The points on which information is here required are similar to those of (*b*) above, with the difference that facilities for attack should be reported instead of those for defence, stretches of the river favourable to the construction of improvised crossings should be reconnoitred and reported in greater detail, and the existence of material on the spot suitable for the construction of these crossings should be noted and some particulars given.

(iii) *Reconnaissance of a Railway.*

308. *Report on a Station.*—It would require an expert to write an adequate report on which to work a railway. Any officer, however, may be called upon to report on a railway station with a view to the entrainment of troops, or to make a preliminary report whereby its suitability as a railhead may be judged. Moreover in a general reconnaissance of an area information regarding railways will usually be of value.

When reporting on a station for the entrainment or detrainment of troops, ammunition or supplies, particulars of the following should be furnished :—

(1) Gauge.
(2) Number of tracks.
(3) Number, length, breadth, and height of platforms.
(4) Number and length of sidings.
(5) Ramps, end-loading and other.
(6) Goods-sheds and buildings suitable as stores, with their nature and floor space.
(7) Approaches to the station.
(8) Forming-up places for troops or transport, with their areas and entrances.
(9) Engine and drinking water.
(10) Turn-tables.
(11) Machine shops.
(12) Stocks of fuel, permanent-way material, and tools.

309. *General and Tactical Reports.*—In a general report, in addition to the details as above for important stations, general details concerning the line should be given, such as :—

(1) Gauge.
(2) Number of lines of way.
(3) Any steep gradients and sharp curves.
(4) Heights of embankments and depths of cuttings.
(5) Details of any important bridges.

In a tactical report it may be sufficient to regard a railway merely from the point of view of the obstacle presented by, or the tactical capabilities of, the embankments and cuttings. In these cases all the necessary information can be given on the enlargement, if one is made.

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(iv) *Reconnaissance of an Area for Supplies.*

310. A thorough report on the resources of an area is a task for an expert, but much useful information can be obtained by a non-expert without going into great detail.

Report generally the commodities that the area produces, in what respects it is self-supporting, and the supplies that come from outside, with their normal sources and channels of delivery. The approximate population should be ascertained, since the area cannot be denuded of supplies, and the amount of the supplies available for the troops will depend on the quantities which must be assigned to the inhabitants for subsistence.

Under headings for various classes of supply record the quantities found and their distribution. Thus :—

(1) Meat.—Approximate amount of any large stores of frozen meat. Numbers of head of cattle, sheep and pigs at farms where stock is kept in any numbers.

(2) Flour.—Ascertain stock held at mills and by principal dealers.

(3) Groceries.—Stocks held by large dealers. Find out intervals at which stocks are replenished and dates of last deliveries. This will give a guide to the number of days' supply likely to be in hand. Generally speaking, only the most important stores, such as tea, sugar and bacon, need be considered.

(4) Hay and (5) Straw.—Stocks held by big dealers and amounts found on farms surplus to their immediate needs.

(6) Fuel.—Any large stocks of coal, wood, or oil, giving an estimate of quantities. Give dimensions of stacks of the two former if unable to ascertain or estimate the weight.

(7) Stocks of petrol held by principal dealers.

(8) Transport.—It may be useful to report to what extent local transport would be available for the collection of supplies into depots or for their distribution.

In every case names and addresses of holders of stocks should be given.

Be careful to distinguish between quantities actually ascertained and those estimated or reported to exist.

A good deal of the required information can be obtained from local authorities, but a proportion of their statements should be verified. They are more likely to understate and conceal stocks than to furnish an over-estimate.

(v) *Billeting Reconnaissance.*

311. *General.*—A billeting reconnaissance may be made with a view either to a record of the capacity of an area or to the definite allotment of billets to a specified force within a specified area.

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In the former case the length of time that the area is to be occupied, together with the relations to the population, whether hostile or friendly, will have to be taken into account. Troops cannot be billeted for long so closely as for short periods. A friendly population must be treated with more consideration than an enemy population. The former must be put to a minimum of inconvenience, whereas in an enemy country the health and comfort of the troops may be made the first consideration, while the accommodation reserved for the inhabitants may in case of need be reduced to a minimum consistent with decency.

The season will affect the billeting capacity of an agricultural district. Between harvest and threshing, barns which at other seasons would accommodate a good number of men will generally be found to be full, and quite large farms may be found to afford little accommodation.

In many civilized countries the local authorities keep detailed lists of billeting accommodation; these should be obtained if possible. They are generally based on the assumption of causing a minimum of inconvenience to householders.

312. *Part I* of the report should include--

(1) A general description of the character of the area from a billeting point of view—whether agricultural, residential, or industrial—and the predominant type of house. The area may be divided, if necessary, into sub-areas of different characters.

(2) A rough statement, in terms of units, of the capacity of towns, villages, hamlets, and any particularly large isolated farms or country houses.

(3) General observations on water-supply, such as source, quality, abundance or scarcity. Note where facilitries for watering animals are good and where they are deficient.

(4) In view of allotment of billets to a specified force, definite proposals as to distribution.

These can best be shown on a large-scale plan. Such questions as supplies, railways, &c., which influence billeting, should not, except by special order, be the subjects of more than general reference in Part I. If requested, they should receive detailed treatment in Part II, on the lines indicated in Arts. 308–310.

313. *Part II* may take a tabular form, such as that which follows.

In the appropriate columns mention any large buildings, with details of capacity, large open spaces and the number of vehicles they would take; likewise buildings suitable and suggested for H.Q. of units or formations, stating what H.Q. they would accommodate.

The position of H.Q., important buildings and open spaces should be marked on a large-scale plan.

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SUGGESTED FORM FOR PART II.

Name of Parish, Town or Village, or Reference No. of Area.	Population.	Billets.			Water Supply.	P.O.		Large Public or other Buildings.	Parks and Open Spaces.	Buildings suitable for H.Q.	Remarks.
		Men.	Horses under Cover.	Horses in Open.		Telegraph.	Telephone.				

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Report also the names and addresses of local authorities.

The sections of F.S.R., Vol. II, which deal with billeting, particularly Sections 47 (10 and 12) and 54 (1 and 13), should be studied, and will suggest other matters on which to report.

Circumstances may demand that the report should deal with measures of security. This will involve reconnaissance and details of an Outpost Position as a distinct feature of the report. In any case it will frequently be advisable to select and report a suitable position for an inlying piquet, and to mention any public buildings, banks or similar institutions on which it is considered that guards should be placed.

(vi) *Reconnaissance of a Position for Attack.*

314. F.S.R., Vol. II, Section 74 (2), gives the main points on which information is required.

Under head (iii) of that section state what constitutes the weakness of any particular point of the defence, *e.g.* :—

(*a*) Deficient field of fire.

(*b*) Difficulty of observation, which may be due to the shape of the ground or to natural cover for attack.

(*c*) Conditions unfavourable to mutual support between adjacent sectors of the defence.

Under head (vi) of the same section include natural obstacles to the movement or advance of the attack, such as rivers, swamps, woods, and dense undergrowth.

As regards head (ix), the best line of attack may depend upon a variety of considerations. It may be either that in which the facilities are greatest or that which is directed towards an objective the capture of which would produce a decisive effect. The report therefore, besides noting those directions of attack where the balance of facilities is most favourable to the attacker, should indicate the tactical points, the loss of which would appear best calculated to weaken the enemy's hold upon his position; it should also consider the factors which determine the possibility of successful attack on these points, as well as the method of its execution.

An attack on a flank is often very effective. Hence if the position has flanks, especial attention should be paid to them and to the factors affecting the prospects of success in an attack upon one or the other of them.

If tanks are available the report should show where conditions are favourable to their action.

Good observation posts, with the approximate areas that they overlook, should be reported.

(vii) *Reconnaissance of a Position for Defence.*

315. The object of the reconnaissance may be either to estimate the capabilities of a position for defence and the force that would

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be required to occupy it, or may have in view its occupation by a specified force. In the latter case, definite proposals as to the location of defences, defensive preparations required and distribution of troops may be called for.

Part I of the report should deal with :—

(1) The extent of the position.

(2) The defensive capabilities of the flanks.

(3) The extent to which the country over which the attacker must advance can be observed.

(4) Possibility of concealment for the defence and facilities for observation on the side of the attack.

(5) Tactical points the loss of which would weaken the general hold of the defence.

(6) Weak points of the position (*see* (*a*) (*b*) (*c*), Art. 314).

(7) Considerations affecting the question of a general counter-attack and its most favourable direction.

(8) Any special features affecting the defensibility of the position not previously mentioned.

316. If the problem is one which calls for concrete proposals, Part I should contain in addition :—

(9) An estimate of the force required.

(10) Proposals for subdivision into sectors, brigade, battalion, &c.

(11) General recommendations as to artillery positions, *i.e.*, positions from which the various sectors can be covered and positions for observing the front they are to cover.

(12) The general line proposed for the infantry defence.

(13) Suggested position for a general reserve, with a brief statement of the arguments in its favour, *e.g.*, cover from observation, facilities for movement in any required direction.

317. *Part II* should deal with the above and some additional points in greater detail.

(1) Observation may be considered from two points of view ; first, general observation of the ground over which the attacker has to advance and in which his artillery would be placed for the support of the attack ; secondly, observation of the ground immediately in front of the defensive lines in order that the artillery may render effective support to the infantry.

Lists of O.P.'s suitable for each purpose should be given, with the areas covered from each.

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(2) Positions suitable for the different types of artillery should be recorded, and an estimate given of the capacity of each in batteries or brigades. Routes to their locations should be marked on the sketch-map.

(3) The defence of flanks, tactical points and weak spots should be examined in detail, and the question of local counter-attack to re-establish the line in such spots considered.

(4) In connection with suggested infantry positions, report on the field of fire, concealment and the possibility of mutual support between neighbouring sections.

(5) Natural obstacles and the extent to which they constitute an obstacle can generally be shown on the large-scale sketch, if one is furnished. Otherwise they must be dealt with in the written report.

(6) The nature of the soil as influencing construction of defences is important.

(7) Any appreciable quantities of tools or materials of use for the construction of defences should be noted.

(8) Communications, both those leading up to the position from the rear and lateral communications within it, should receive attention.

(9) It may be necessary to consider the employment of tanks by either side. For the defence, report on suitable concealed assembly positions and routes to and out of them; as regards the attack, note likely assembly positions and ground favourable to tank action.

(10) Drinking-water is an important consideration if the position is likely to be occupied for some time.

318. *Delaying Position.*—In a report on a position which is to be occupied by a rearguard merely as a delaying position, the most material requirements are :—

(1) Distant observation for the defence.

(2) Field of fire for machine-guns and rifles.

(3) Concealment.

(4) Routes for withdrawal.

(5) Avoidance of the danger of the enemy working round the flanks unobserved.

§84. General Hints.

319. *Hints for a Sketch-map.*

(*a*) *Clearness and Legibility* are the first essentials in finish. The sketch may have to be read in a poor light and it is also important that the eye should be able to detect quickly the information desired.

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(*b*) Undoubtedly the best *Finish*, if time and facilities permit, is in waterproof ink; ordinary ink should not be used.

If pencil is used, lines must be firm and black. A pencil too hard will not give a line sufficiently black; with a pencil too soft it is difficult to keep the lines fine and firm, and there is a tendency to smear.

In making the enlargement, use a fairly hard pencil, H or 2H, and keep lines fine and light. A hard pencil heavily used makes furrows in the paper which cannot be removed by rubbing out. With a soft pencil, if much rubbing out has to be done, smearing is inevitable. Remember that detail enlarged from the original may have to be amended and altered on the ground. For finishing an F or HB is suitable. It is essential for good work to keep a sharp point on the pencil throughout.

The use of conventional colours—inks or chalks—improves both the appearance and legibility of a sketch (*see* Plate XVIII).

(*c*) *Excess of Written Information* on the body of the sketch obscures detail and impairs legibility. Any but the shortest descriptive notes which it is desired to put on the sketch should be written in the margin opposite to the feature to which they refer; add a reference number, thus (3), against the note and at the point on the sketch to which it refers.

Similar reference numbers or letters may be used to identify unnamed points to which it is desired to refer in the report.

It is best not to number points until it is decided what points will require reference numbers, and then to allot them systematically; *e.g.*, for a road report, in the order of the route followed; for a position, from right to left. Any system will suffice, the object being to obviate the loss of time spent in searching amidst a promiscuous assignment of numbers.

(*d*) Where *Roads and Railways* run off the edge of the sketch, mark against them the name and distance in miles of the next, or an important, village or town on them.

(*e*) All *Lettering and Writing* should be entered so as to be easily legible when the sketch is held with the north point at the top.

(*f*) Every sketch should show the following *References*:—

(1) A heading stating the purpose of the reconnaissance.

(2) A scale of yards about 6 inches in length. A statement of the V.I. used.

(3) A North Point. A magnetic North point is of relatively little value without a statement of the variation. If possible True North should be shown as well and the variation given.

(4) The clear signature of the sketcher, with date.

(5) A statement of the weather conditions under which it was made.

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(*g*) As a rule, only the enemy's *Works and Troops* should be indicated. Our own troops should be marked in only by special order or if the purpose of the report clearly requires that they should appear.

320. *Hints for a Report.*

(*a*) *Accuracy* is of great importance. When any assertion made is not a matter of the personal knowledge or observation of the person rendering the report, that fact must be stated. The source of such information or some indication of the degree of reliability to be attached to it should be given.

(*b*) *Notes* should state facts, not be couched in the form of orders. Such expressions as "Guns will occupy (3)," "Infantry will advance *via* Deep Lane," should be avoided. The correct form for them would be "Good position for an 18-pdr. battery at (3)," "Covered approach for infantry (4) to (5)."

(*c*) All *Proper Names* must be written in block capitals. Be careful to spell them correctly. There may be two places close together very similar in spelling. For instance, on the 1-inch Ordnance Survey maps of Brighton district there are two hills, ITFORD and IFORD, only three miles apart. It is not uncommon for two places, particularly two farms, within a short distance of one another, to bear the same name. Be on the lookout for such cases and make it quite clear to which the reference is intended.

Where an Anglicized form of a foreign name exists, it should be given, and may be followed by the local name in brackets. Otherwise the spelling should follow the rules adopted for British official use, as given in Appendix IV.

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APPENDICES.

Appendix I.

LIST OF BRITISH, DOMINION, COLONIAL, AND FOREIGN MAPS.

§85. Topographical and Military Maps.

321. *List.*—The list of maps which follows is not exhaustive, but includes all the better-known series within the range of scales given.

Scales, 1/20,000 *to* 1/400,000.

Country.	R.F. 1 to	Vertical Interval *ft.* or *m.*	Notes.
		Europe.	
United Kingdom	10,560	100 ft.	Six-inch topographical and cadastral.
	20,000	5 m.	Military gridded map.
	63,360	100 ft.	Inch, published in two forms: (1) in black with contours; (2) in colours with contours and hachures.
	63,360	50 ft.	Inch. Military and Popular.
	126,720	100 ft.	Half-inch: (1) contours and hill shading; (2) contours and layer colouring.
	253,440	200 ft.	¼-inch. Old series, hill shading; new from 1919 with layer colouring.
Austria-Hungary, &c.	25,000	5–20 m.	Hachures and contours.
	75,000	100 m.	Hachures and contours.
	200,000	....	Central Europe. Hachures, but parts of Balkan area contoured at 100 m. interval.
Belgium	20,000	1 m.	Note the interval.
	40,000	5 m.	
	100,000	10 m.	
	160,000	5 m.	
Bulgaria	40,000	10 m.	S. and W. Bulgaria, in black only.
	50,000	10 m.	S.W. of Sofia, in colours.
Denmark	20,000	1·25–2·5 m.	5-ft. contours on old series.
	40,000	10 ft.	
	160,000	5 m.	Black edition from engraved plates.

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Country.	R.F. 1 to	Vertical Interval *ft.* or *m.*	Notes.
		EUROPE—*continued.*	
France	20,000	10 m.	Plans Directeurs.
	20,000	5 m.	British War Series.
	50,000	10 m.	New Staff map in colours (in progress). Hill-shaded.
	80,000	....	Old Staff map in black only with hachures.
	200,000	20 m.	Contours and hill shading.
Germany	25,000	5 m.	
	25,000	10 m.	Forest lands.
	50,000	20 m.	Bavaria.
	100,000	50 m.	Hachures and contours. New edition in colours.
	200,000	20 m.	10 m. interval in parts.
	250,000	50–500 m.	Bavaria. Layered and hill-shaded.
	300,000	....	Central Europe. No contours. Hill-shading.
Greece	75,000	10–20 m.	Thessaly, Attica and region around Salonica.
Italy	25,000	5-50 m.	In black.
	50,000	5-50 m.	In black.
	100,000	50 m.	Black and coloured editions, both with hachures.
	200,000	100 m.	In colours with hill-shading.
Netherlands	25,000	10 m.	In colours with hachures.
	50,000	10 m.	In colours with hachures.
	200,000	....	Black and coloured editions, both with hachures.
Norway	100,000	30 m.	Hill-shading.
	250,000	50 m.	Hill-shading in colours.
Poland	100,000	2·13 or 4·27 m.	German Staff map produced during the war.
Portugal	50,000	25 m. ...	Coloured. In progress.
	100,000	25 m.	Black only.
Rumania	50,000	10 m.	Coloured, except in Western Walachia.
	100,000	5·25 m.	In colours; includes Transylvania.
Russia	126,000	....	Hachures. Includes Poland.
	420,000	....	Hachures, coloured. Includes Poland and Finland.
Spain	50,000	20 m.	South-Central Spain from north of Madrid to Gibraltar. In colours.
	100,000	50 m.	In colours; only a few sheets have yet appeared.
Serbia	75,000	50 m.	See the Austrian Staff Map.
	150,000	50–100 m.	Incomplete. In colours.
	200,000	100 m.	Serbian revised edition of Austrian Staff Map.
Sweden	100,000	....	Southern half of Sweden. Hachures and form lines.
	200,000	15 m.	Northern half of Sweden. Combination of contours and hachures. In wooded areas hachures only.

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Country.	R.F. 1 to	Vertical Interval *ft.* or *m.*	Notes.
		EUROPE—*continued.*	
Switzerland	25,000	10 m.	Except regions covered by 1/50,000. In colours.
	25,000	8 or 4 m.	Exceptional districts.
	50,000	30 m.	Alpine districts not covered by 1/25,000. In colours.
	100,000	....	In black. Hachures.
Turkey	25,000	10 m.	Turkish Survey.
		ASIA.	
Arabia	253,440	....	¼-inch. 9 compiled sheets of Red Sea coast and about 120 miles inland from Mokka to Mecca. Horizontal hachures.
Aden	253,440	....	¼-inch reconn. Survey. Hachures.
Caucasia	21,000	35 ft.	½ verst to 1 inch. Special areas.
	42,000	35–70 ft.	1 verst to 1 inch. Greater portion of Western Caucasia.
	84,000	70 ft.	2 versts to 1 inch. Ditto and part of Armenia and Persia.
	210,000	....	5 versts to 1 inch. Hill-shaded Russian map.
	210,000	....	5 vérsts to 1 inch. W.O. transliteration, 1885. Hill-shaded.
Ceylon	63,360	100 ft.	1-inch. New map in prog. in colours, with hill shading.
	253,440	....	¼ inch.
China	200,000	....	German reconn. and compilation in Chili and Shantung. Hill-shaded.
			Various compiled maps on small scales. Foreign concessions on larger scales.
Cyprus	63,360	....	Based on Trig. Survey by Lt. H. H. Kitchener, 1885. Hill-shaded.
	348,480	....	5½ miles to 1 inch, 1907. Hachured.
Hong Kong	25,534	50 ft.	2½ inch = 1 mile, W.O., 1913.
	84,480	....	1⅓ mile = 1 inch. W.O., 1899; revd. 1909. Form-lines.
India	63,360	50 ft.	1-inch. In progress.
	126,720	100 ft.	½-inch. In progress.
	253,440	....	¼-inch. 1827–86 Atlas series. Hachured.
	253,440	250 ft.	¼-inch. New Degree Sheet series in progress. Political and layered editions.

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Country.	R.F. 1 to	Vertical Interval *ft.* or *m.*	Notes.
		ASIA—*continued.*	
Indo-China	100,000	25 m.	Hill-shaded. Tonkin and coast districts of Annam.
	200,000	50 m.	Tonkin (in progress).
Japan	25,000	10 m.	Names in Japanese. Imp. Japan Survey.
	50,000	10 m.	Names in Japanese. Imp. Japan. Survey.
	200,000	50 m.	Names romanized.
Java	100,000	50 m.	Banjoemas Residency and parts of Batavia, Kedoe and Semarang.
Korea	50,000	20 m.	Imp. Japan. Survey.
Malaya	63,360	50 ft.	F.M.S. Survey. A few sheets in Perak, Negri Sembilan and Dindings.
Mesopotamia	63,360	25 ft.	M.E.F. surveys.
	126,720	100 ft.	M.E.F. surveys.
	250,000	....	G.S.G.S. compilation. Hor. hachures.
	250,000	250 ft.	New series.
	253,440	....	M.E.F. surveys. Form-lines.
Palestine	20,000	30, 65, 100 ft.	E.E.F. surveys.
	40,000	30, 65, 100 ft.	E.E.F. surveys.
	63,360	....	Palestine Expln. Fund. Hill-shaded.
	168,960	....	Palestine Expln. Fund. Hill-shaded. 2⅔ miles to 1 inch.
	200,000	50 m.	Turkish reconn. survey.
	250,000	....	G.S.G.S. compilation. Hill-shaded.
Siam	50,000	?	Imp. Siamese Survey. Over 50,000 sq. kms. covered by published maps.
	100,000	....	
	200,000	....	New "degree sheet" series begun.
Siberia	....	....	Russian 40-verst compilation, 1/1,680,000. Hill-shaded.
Syria	200,000	50 m.	Turkish reconn. survey and French transliterated reproductions.
	250,000	....	G.S.G.S. compilation. Form-lines or hill-shading.
Turkey in Asia ...	25,000	10 m.	Dardanelles and part of Ismid Peninsula. Turkish.
	50,000	10 m.	Ismid Peninsula. Turkish survey; next series also.
	200,000	50 m.	From lat. 37° northwards and from long. 36° eastwards to frontier.
	250,000	....	G.S.G.S. compilation. Form lines.
	400,000	....	German compilation. Hill-shaded.

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Country.	R.F. 1 to	Vertical Interval *ft.* or *m.*	Notes.
		AFRICA.	
Algeria	50,000	10 m.	Whole of coast region, 150–160 sheets. Hill-shaded.
	200,000	50 m.	Serv. Géog. de l'Armée. Hill-shaded.
	200,000	100 m.	Algerian Govt. Hill-shaded.
Basutoland	250,000	100 ft.	G.S.G.S. 4 sheets covering whole.
Cape of Good Hope	250,000	100 ft.	G.S.G.S. reconn. survey. North of 32° S. only. 32 sheets.
Egypt	50,000	10 m.	Cultivated area.
	100,000	5–30 m.	Cultivated area, west littoral, &c.
Eritrea	100,000	100 m.	A central quarter of the colony. Contours and hill-shading.
	400,000	....	Probably compilation from diverse material. Hachures.
Gold Coast	125,000	....	Coast to 7° N.
	250,000	....	7°–8° N. Provisional sheets.
Kenya Colony	125,000	100 ft.	Nairobi, Malindi and neighbourhoods. 10 sheets.
	250,000	200 ft.	Mombasa to Lakes Victoria and Baringo. 19 sheets.
Morocco	100,000	....	Spanish Staff map of Tangier, Ceuta and Tetuan. Form-lines.
	100,000	....	Spanish Staff map of Melilla region. 5 sheets (1920). Form-lines.
	100,000	50 m.	French series in prog. Rabat, Meknes, Fez. 4 sheets (1920).
	200,000	50 m.	Same region as above. 3 sheets (1920).
Natal	63,360	....	North of Ladysmith. Form-lines.
Nigeria	125,000	50 ft.	Western portion of Southern Province. 15 sheets.
Nyasaland	250,000	....	3 sheets of country between Lakes Nyasa and Tanganyika. Form-lines.
Orange Free State	125,000	100 ft.	Southern two-thirds completed. 55 sheets in all.
Rhodesia (Northern)	250,000	100 ft.	3 sheets in North-eastern Rhodesia. Some boundary maps also.
Senegal	100,000	10 m.	Coast region from Senegal River to Gambia.
Sierra Leone	63,360	100 ft.	The péninsula only in one sheet.
Sinai	125,000	100 ft.	The northern portion of the peninsula. 23 sheets.
	250,000	100 ft.	The northern portion of the peninsula. 4 sheets.
Somaliland (Italian)	50,000	5–10 m.	Lower Juba region only.
	200,000	....	Southern coast region. Form-lines.

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Country.	R.F. 1 to	Vertical Interval *ft.* or *m.*	Notes.
		AFRICA—*continued.*	
S.W. Africa	100,000	25 m.	14 sheets in neighbourhood of Karibib and Windhoek.
Sudan	250,000	....	About 150 sheets mainly compiled.
Tanganyika Territory	100,000	25–100 m.	German sheets. Usambara (4 sheets); Massoko (1 sheet).
Transvaal	125,000	100 ft.	G.S.G.S. maps. Transvaal Manœuvre area. About 12 sheets.
Tripoli	100,000	30·50 m.	Coast in vicinity of Tripoli and inland to Garian. The 10 m. contours are interpolations.
Tunisia	50,000	10 m.	Northern Tunisia. Hill-shaded.
	100,000	25 m.	Northern Tunisia excepted. Hill-shaded.
	200,000	50 m.	Covering nearly the whole country. Hill-shaded.
Uganda	250,000	100–200 ft.	13 sheets, covering more than half the Protectorate.
		AMERICA.	
Ontario and Quebec	63,360	25 ft.	About 5,000 sq. miles near the Great Lakes covered by these two series.
	126,720	25 ft.	
British Colombia	160,000	250 ft.	Frontier of Alaska in co-operation with U.S.A.
	253,440	....	About 5,000 sq. miles near the frontier of the State of Washington covered by these two series. Hachures and spot heights.
	506,880	....	
Yukon	380,160	....	6 m. to 1 inch. From photographic surveys. 10 sheets (incomplete). Excellent form lines and shading.
United States	62,500	10–25 ft.	New England States and Ohio, N. Carolina, Wisconsin and Iowa, Louisiana, California (some with 50-ft. contours).
	125,000	100 ft.	Virginia, Tennessee, Alabama, Missouri, Arkansas, Dakota, Nebraska, Kansas, Colorado, Texas, Washington, Idaho, California.
	250,000	200 ft.	Montana, Utah, Arizona, New Mexico, Oregon, Nevada.
Argentine	100,000	2·5 m.	3 sheets near Buenos Ayres.
Brazil	100,000	50 m.	Small areas in Province of Minas Geraes.
	100,000	25 m.	Small areas in Province of São Paulo.
Chile	25,000	10 m.	In black. Neighbourhood of Iquique and Concepcion.
	250,000	....	Argentine boundary. Hill-shading and spot heights. Little detail.
Uruguay	20,000	5 m.	Dept. of Montevideo.

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Appendix II.

NOTES ON PROJECTION OF MAPS.

§86. Definition, Error, Classification and Selection.

322. *Introductory.*—The theory of map projections is, generally speaking, beyond the scope of this Manual. The word "projection" is, however, so frequently used in speaking of maps that it is desirable to give some explanation of what the word means and of what importance the subject is in the military sense.

Explanation.—In a sketch of a small area there arises no question of projection. But in a large area, such as that of a country, the method of representing the topographical detail at once demands consideration.

In carrying out a survey one of the first problems encountered is that we are dealing with objects on the surface of a sphere (approximately), whereas it is necessary to draw them on a sheet of paper, which is a plane surface. Now it is impossible to do this with absolute accuracy. In transferring from a spherical to a plane surface some degree of distortion is unavoidable. Various methods have been devised for representing geographical detail on a plane; these methods are called "projections."

Different projections have different characteristics. One projection, for example, will represent areas correctly, while distorting shape; another, while preserving local shape, will introduce errors in area. In general, it may be said that a projection may be designed to preserve any one quality, *e.g.*, local shape, with little or no error, but that this has to be done at the cost of some other quality, *e.g.*, equivalence of area; it is impossible to represent everything correctly.

323. *Choice.*—We, therefore, choose a projection according to the purpose for which a map is intended. If it is a map for showing areas, we must use a projection which shows areas as correctly as possible, at the cost of accuracy in shape. If, as is the case in military maps, shape—which implies accuracy of direction or bearing in the vicinity of a point—is of importance, we must secure these as far as possible, and let true representation of area go by the board.

324. *Error.*—All maps must be, generally speaking, subject to linear or scale error. Were there no such error, the representation would be perfect, which is impossible. It may be said at once, however, that the scale errors involved are not in general sufficient to affect maps for practical purposes so far as their military use is concerned.

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The second class of error is angular. Angular errors are more important than scale errors from the point of view of the artillery; it is for the artillery in particular that the question of projection demands consideration.

The errors, linear and angular, are not uniform over a map, but increase usually as the square of the distance either in one direction outwards from a given line or sometimes in all directions outwards from a given point. Nor are errors always the same in all directions around any point.

325. *Classification.*—Projections are divided into various broad classes according to the way in which they are produced. Thus, if a cylinder were supposed to touch the earth along the Equator, and the net of meridians and parallels, supposed elastic, were as it were unwound from the sphere and affixed to the inside of the cylinder, the meridians would become straight lines on its surface parallel to its axis, and the parallels would become circular sections of the cylinder. Now suppose the cylinder cut along one of the straight lines and unfolded till the surface became flat. The map is then said to be *developed* on the surface of the cylinder and the projection is called by courtesy *cylindrical.*

In the same way the map may be developed on the surface of a cone touching the earth along a given parallel; the projection is then termed *conical.* By an extension of this principle, a series of cones, or rather segments of cones, may be employed, giving a *polyconic* projection.

Similarly the map may be represented on a plane touching the earth at a given point (*Azimuthal* and *Perspective* projections).

326. *Leading Forms.*—Each class of projection—cylindrical, conical, &c.—may assume three leading forms, the *equivalent,* the *orthomorphic,* and certain third forms, intermediate between the other two, which may be grouped as *natural.*

The chief characteristic of the equivalent forms is that they represent areas correctly, but errors of bearing reach a maximum and errors of scale vary greatly around any point. This form of projection is adapted to statistical, but not to military purposes.

In the orthomorphic form, shape, and hence bearing is perfectly preserved in the immediate vicinity of a point; even in the case of long lines the error of bearing is kept within very narrow limits; and scale errors are the same in all directions round a point. It is then the best form for the artillery and surveyors.

In the natural forms, distortion of bearing is less than in the equivalent, and scale error is less than in the orthomorphic. The natural forms are, in fact, compromises between the other two.

327. *Factors determining Choice.*—In Article 323, it was stated that one should choose according to the *purpose* for which the map is intended. This is the chief consideration, but there are others. Second in importance is the *configuration* of the area to be portrayed. Thirdly, in special cases the *position* on the

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earth's surface may be the controlling factor, as for example, in the case of polar charts.

When the country is a zone of great depth in latitude and small width in longitude, a projection suitable to this configuration is termed *meridional*. When the area consists of a belt of country of small depth in latitude and great width in longitude, a suitable projection is termed *longitudinal*.

It is unnecessary to go in any detail into the question of the numerous projections from which the choice must be made. It will be sufficient to mention, with their chief characteristics, a few of those in common use.

§87. A Few Common Forms of Projection.

328. *Mercator.*—Cylindrical, the cylinder being tangent to the earth along the Equator. Orthomorphic. Scale error increasing as the square of the distance from the Equator; at latitude 60° it amounts to 100 per cent. A curve of constant bearing (named a *loxodrome*) on the earth's surface becomes a straight line on the projection, and it is this peculiarity which makes the projection so valuable to navigators; it is, therefore, in universal use for Charts. The earth's pole is at infinity and the projection is useless above 75° of latitude. The scale error being constant along a parallel, the projection is longitudinal. The grid and graticule are parallel.

329. *Cassini.*—Cylindrical, the cylinder in this case being tangent to the earth along the initial meridian of the map. A natural projection; much more commonly used by surveyors than any other, being easily worked in the field. In this projection, the map is plotted simply from the rectangular co-ordinates, which are treated as if on a plane system. The angular and scale errors increase as the square of the distance from the initial meridian. The distortion of bearing is zero in azimuths 0°, 90°, 180°, 270°, and has its greatest value in azimuths 45°, 135°, 225°, 315°. The scale error has its greatest value when the line bears north or south and is zero when the line bears east or west. The projection is meridional, but can be easily modified to suit a country of large extent either in a N.E.—S.W. or N.W.—S.E. direction, or in both. The projection is that used for the new 1/20,000 map of Great Britain.

330. *Transverse Mercator.*—This, also known as the Gauss Conformal, is the orthomorphic form of the Cassini projection. The angular error round a point is of course nil, and the scale error is constant in all directions round a point; but being equal to the local maximum scale error of the Cassini system, it follows that in the Transverse Mercator the error of area is doubled in comparison with the Cassini. This is the best projection for surveyors working in a country with large extent in latitude but small extent in longitude, since the working formulæ of the

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Cassini can be very simply modified, and the grid bearing (except on long lines) is in perfect agreement with the bearing derived from the rectangular co-ordinates considered as a plane system. The Transverse Mercator is used in Hanover, Egypt and the Gold Coast Colony.

331. *Bonne.*—Conical, equivalent and longitudinal; used in France, Belgium, Scotland, &c. A poor projection for military purposes, and unsuitable for a country of considerable extent in latitude.

332. *Conical Orthomorphic.*—Often known as the Lambert. A good longitudinal projection, but not so suitable for surveyors as another known as the *Transverse Cassini.* The principal axis is the parallel of latitude though the origin and the scale error increases as the square of the distance from this parallel. It was intended that this projection should replace the Bonne on the Western Front.

333. *Polyconic.*—The map, instead of being referred to a single cone, is developed on the surfaces of continuously changing cones, each with its apex on the earth's axis. The graticule is easily plotted from tables and hence the projection is largely used for topographical purposes, nearly all large-scale G.S.G.S. maps being now plotted on the polyconic, a serial projection which can be applied to the whole world. Single small-scale G.S.G.S. sheets with R.F.'s of between 1/2*M* and 1/5*M* are commonly plotted on a variety of the projection known as the *Rectangular Polyconic.* Another variety is used for the 1/*M* maps of the international *Carte du Monde,* and this form has also been applied to a series of international maps of Africa on the scale of 1/2*M*.

§88. The Grid on a Projection.

334. *Conditions of a Grid.*—Every projection which is to be used as a basis for maps which are to show a grid—as distinct from a system of mere squaring—must comply with certain conditions :—

(1) The projection must be referred to a single meridian.
We cannot have each individual sheet plotted on its own projection, even though the form of projection is the same of all.
Consequently in a polyconic series of maps, each of which is based on its own meridian, there can be no single grid.

(2) This single meridian should be central to the country portrayed.
Otherwise the errors of projection will be greater than necessary.

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(3) The central meridian must be plotted as a straight line, an axis of the grid, however the other meridians may appear.

The Mercator is practically the sole projection on which all the meridians are parallel straight lines. The grid and graticule are then parallel systems.

(4) All the rectangular co-ordinates of points in the territory must be computed with reference to the central meridian as origin of bearings and to a point on this meridian as origin of distances on the grid.

(5) Whatever projection be used, it is advisable that it should not be such that the derivation of the rectangular from the geographical co-ordinates is fraught with difficulty.

Especially suitable for field purposes are projections in which the rectangular co-ordinates of a point can be *accurately* derived directly from the rectangulars of a neighbouring point without excessive computation, given the bearing and distance between them. This is known as " point-to-point working."

The origin mentioned in (4) is the " true origin." In order to have the co-ordinates south and west of the true origin positive, it is customary to add certain round lengths to both the E.—W. and S.—N. co-ordinates of the whole system. These additions transform the co-ordinates to an apparent origin outside the extreme south-west of the country; the point thus reached is named the " false origin."

Bearings on gridded maps should always be referred to the grid line through the point in question. These grid bearings, reckoned from " Grid North," may have to be converted to true bearings, reckoned from True North, or *vice versa*. The manner of converting from one to the other is described in the next article.

335. *Convergence.*—The angle at any point between the grid line and the meridian of that point is the convergence of meridians at the point. It is then otherwise defined as the deviation of the grid from the graticule at any point. It varies slightly with the nature of ordinary forms of projection (the Mercator excluded), but not to an extent to be considered here.

In the northern hemisphere, to obtain the grid bearing from the true bearing, the convergence must be subtracted if the point is East of the central meridian; if West of the central meridian, the convergence must be added to the true bearing to derive the grid bearing.

The convergence may be calculated from a large-scale map, like the new 1/20,000 of England, which shows the points where the graticule cuts the top and bottom of the sheet. Measure the distances at top and bottom from the meridian cutting to the

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nearest grid line and take the difference; divide this difference by the depth of the sheet. The result is the tangent of the convergence, which is accordingly taken from a table of natural tangents.

To obtain a more correct value one may compute the convergence for two meridians on either side of the point and interpolate for the difference between the results, distributing it proportionately to the distance of the point from either meridian. This method applies to large-scale maps only.

If we know the longitude of the central meridian and the latitude and longitude of the point, the convergence is $\omega \sin \lambda$, where ω is the difference of the two longitudes and λ the latitude of the point. Or if we know the co-ordinates of the point referred to the *true* origin, the east—west co-ordinate being x; the convergence is in seconds approximately—

$$\frac{206{,}265\ x \tan \lambda}{\text{Earth's Radius}}.$$

If x is in metres, the radius must be taken in metres (6,370,000); if x is in feet, the radius in feet (20,900,000).

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Appendix III.

LAND FORMS.

§89. The Effects of Upheaval and Degradation in Moulding the Surface.

336. The present Appendix contains matter of great practical interest to topographers and sketchers. But in a work of this nature nothing beyond a mere outline of the subject can be given, sufficient however to form an introduction for the student who is interested. For further information he must consult those sections of the works cited below which particularly treat of the subject.

Denuding and Uplifting Agencies.—The varied shapes which diversify the land surface betray their origin to the eye of a trained observer. This is because different physical conditions produce special types of land form.

In 1913 a topographical survey was made in Sinai by officers and N.C.Os. who were capable topographers but had no special knowledge of the origins of land forms. The resulting map formed such a complete topographical record that a student of land forms had no difficulty in extracting from it the geological structure, hitherto unknown, of this region.* In this case sufficient time was available for systematic plane-table work; but it will be seen that where this is not so an officer with a knowledge of land-form types will make a more accurate reconnaissance sketch than one who has not this advantage; for on recognizing the type in nature he will be able in drawing form-lines to use the knowledge previously acquired of similar types and of their representation on maps.

In the following pages, therefore, the relation of a selection of typical forms to their origins will be illustrated.

The entire land surface of the earth is undergoing a process of denudation by which a variety of natural agents aided by gravity are steadily removing material from it and depositing it in the ocean, thus gradually lowering the land surface. In time this denudation would wear the land down to sea-level, while the waves would continue the work even below that level. But in compensation there are movements in the earth's crust operating from time to time to produce the opposite effect, either of elevation of sea bottom to become new land surface or of raising low land surfaces to a higher level above the sea.

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* *See* below, Art. 341.

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The existing land features are the result of the contest of these two great forces of upheaval and degradation, and their character in detail bears a close relationship to the nature of the rocks forming the earth's crust.

337. *Structure, Agents and Stage of Erosion.* — In order to understand the shapes of any particular land surface we must ascertain three main facts about it; first, the relation of the surface to the underlying *rock structure*—what is the kind of the rocks, what is their posture, and at what sort of angles do they meet the surface; secondly, the nature of the *processes* of decay and denudation acting at the surface or beneath it; and thirdly, the *stage* which has been reached in the denudation, for surfaces are with good reason described as "young," "mature," or "old."*

In this chapter the features characterizing different *rock structures* will receive most attention, as these are on the whole the most useful for first study by the topographer. But the more striking topographical effects of several processes will be dealt with briefly and mention will be made of the features in which the time element is the most important.

338. *Structure of Rocks.*—Rocks are either stratified, *e.g.*, sandstone, or massive, *e.g.*, granite. They are said to be "strong"

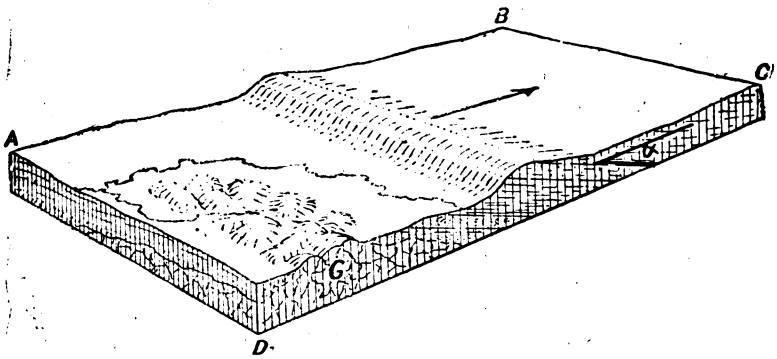

Fig. 66.—Outcrop, Strike, and Dip of Strata.

where relatively resistant to agents of erosion, or else "weak." The strong rocks therefore tend to form the high ground and

* For the systematic treatment of this subject the reader must consult the leading recent works on physical geography, of which the following are recommended:—

W. M. Davis, *Physical Geography*, pp. 432. Ginn and Co., Boston, 1898.
R. I. Salisbury, *Physiography.*
E. de Martonne, *Traité de Géographie Physique*, 3rd ed., pp. 922. A. Colin, Paris, 1920.
United States Geological Survey. *The Interpretation of Topographic Maps.*
Service Géographique de l'Armée, *Les Méthodes et les Procédés de Géodésie, de Topographie et de Cartographie.* (Col. Vidal.) Imprimerie du Service, Paris, 1912–13.

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weaker rocks the lowlands and valleys. Where stratified they either lie horizontal or dip at varying angles from the horizontal. The direction perpendicular to the direction of maximum dip of a bed of rock is called its "strike," and the edge presented at the surface of the ground is called its "outcrop."

In the block of country A, B, C, D, Fig. 66, in which the surface is shown and also two cross sections of the strata, let A D be east—west and C D north—south. Then the rock stratum which from its relative strength forms the straight ridge is said to dip in the direction of the arrow, *i.e.*, northwards; the amount of "dip" is measured from the horizontal—here α degrees—and the strike is E.—W. The outcrop (shown by dotted lines along the ridge) here corresponds with the strike. A massive (igneous) rock, such as granite, is shown in section (G). This rock, as it is relatively strong compared with all save one of the sedimentary strata which rest upon it, appears at the surface as an oval hilly area.

339. The surface developed by the normal processes of weathering and erosion acting upon stratified rocks lying horizontally is illustrated in Figs. 67, 68 and Plate XXV.

Fig. 67 is a map in which the contour interval is uniform, and Fig. 68 is a block diagram of the same area viewed from A towards B.

The rocks are alternately weak and strong, and a series of steps results throughout the area, with tabular hills becoming isolated as the dissection by streams proceeds. In each case the strong rock remains as a steep cliff while the weaker beds have gentler slopes. There is no regular arrangement of the drainage or of the form of the plateaus in plan. But the cross-section of the valleys varies only in size. If the topographer notes the vertical interval between the strata and the fact that they lie horizontally he will be greatly helped in successfully and rapidly representing the valley slopes.

Plate XXV, from an oblique air photograph of part of the left bank of the Jordan River, shows a plateau of this character. But here dissection has not proceeded so far as in the case illustrated above.

340. The surface developed by the normal processes acting upon stratified rocks of unequal strength which lie in a *tilted* position is illustrated by Figs. 69 and 70, which show a map and a block diagram of the same area. In this case the chief features are the parallel scarped ridges corresponding to the strong rocks, the steep escarpment in each case facing away from the direction of dip of the strata. A common though not invariable feature of such surfaces is the drainage of the low belts by streams cutting across the ridges in gorges.*

* For the explanation of this, reference must be made to the text-books.

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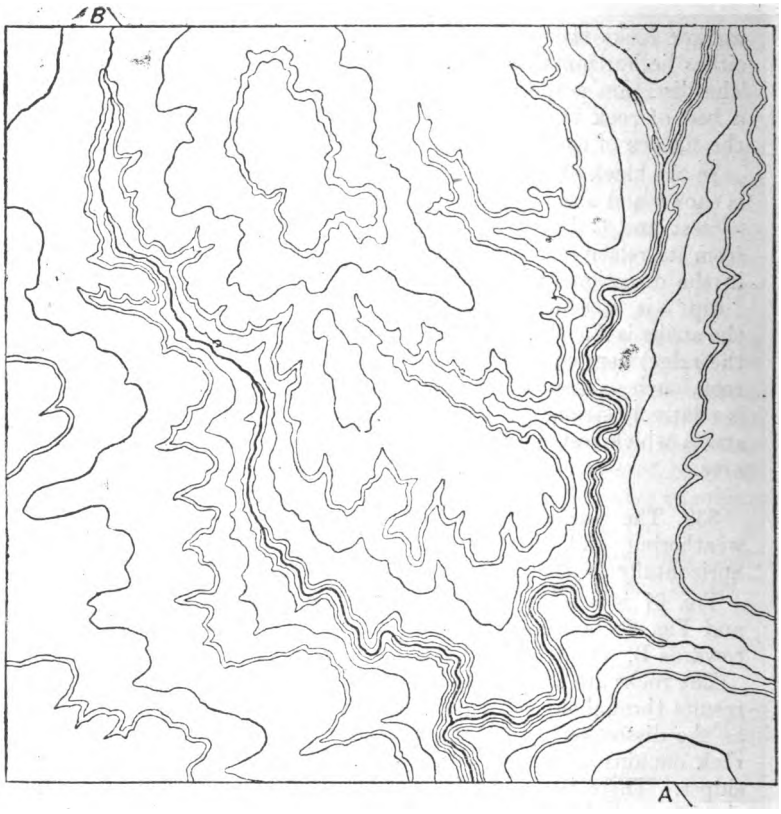

FIG. 67.—Alternation of Weak and Strong Horizontal Rocks.

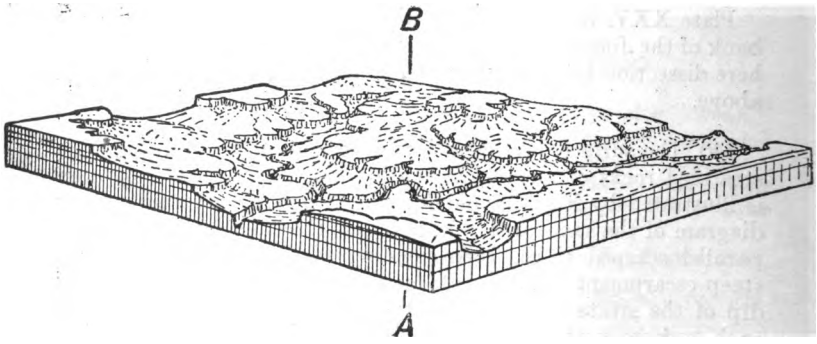

FIG. 68.

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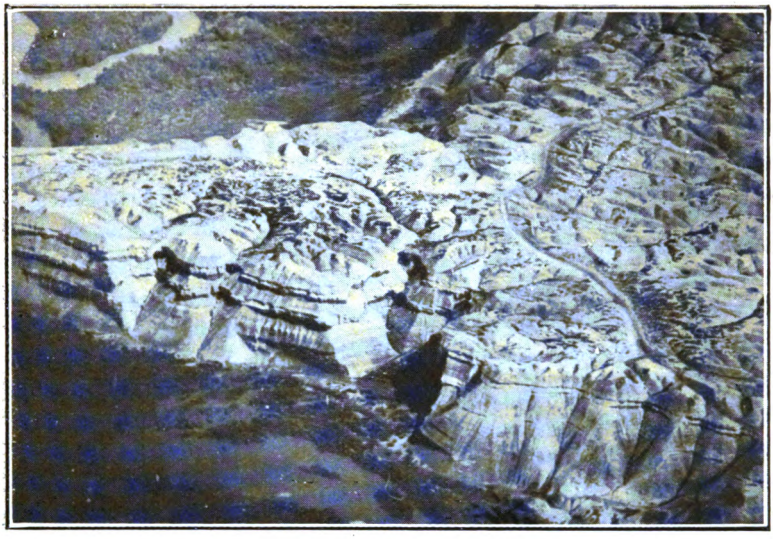

PLATE XXV.

Eastern Scarp of Jordan Valley.

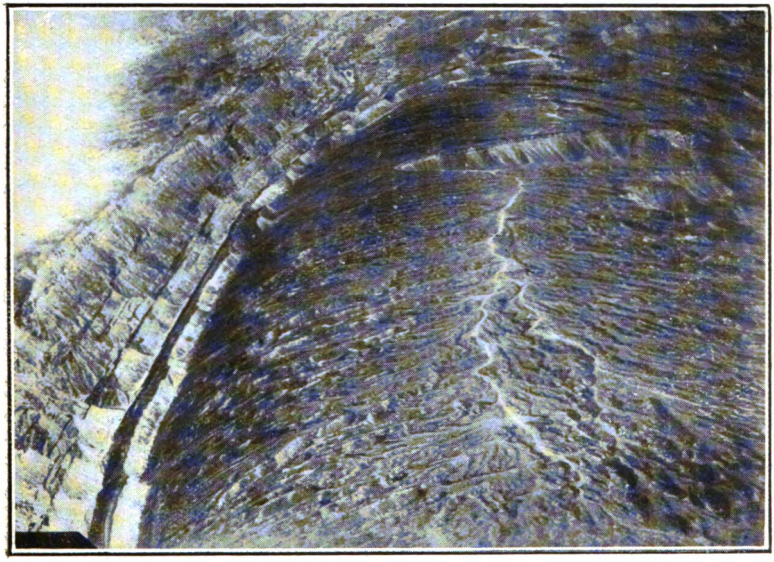

PLATE XXVII.

Anticline in Persia.

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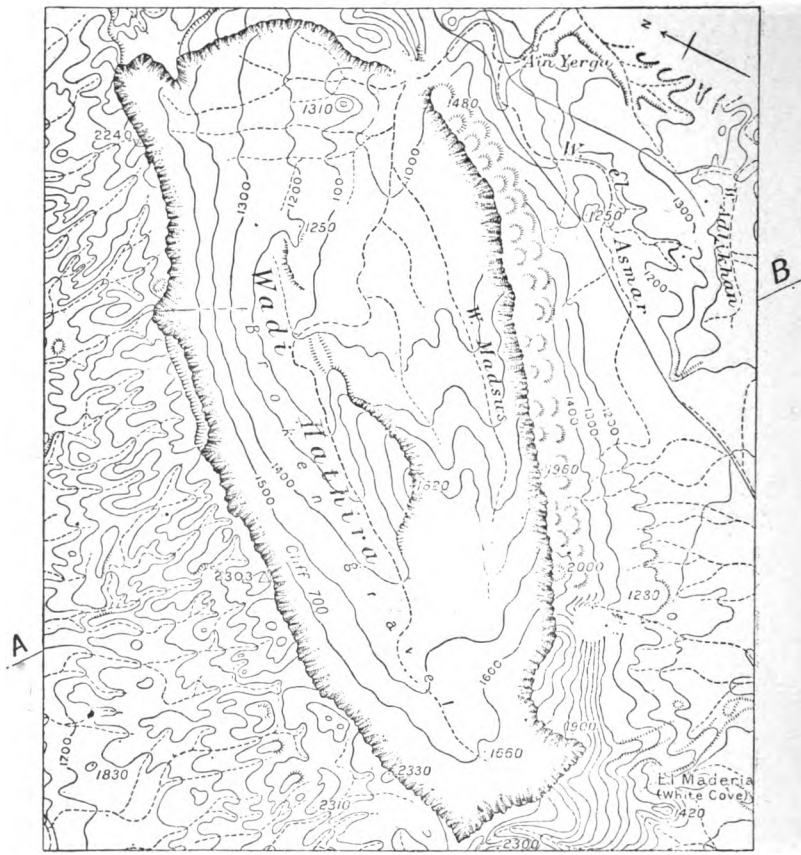

V.I. 100′ PLATE XXVI. Scale 1/125,000

Eroded Dome in Northern Sinai.

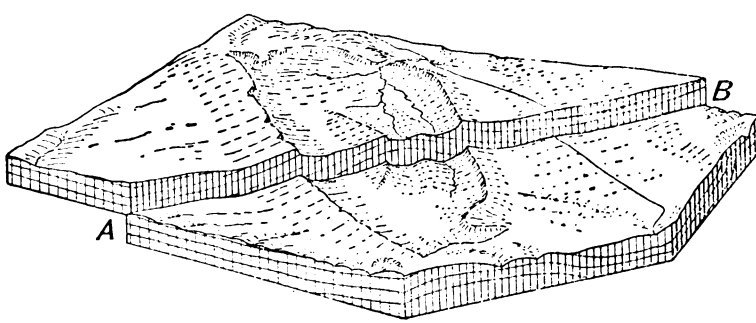

FIG. 71.

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The topographer would recognize the nature of this rock structure and ascertain the relative heights of the successive

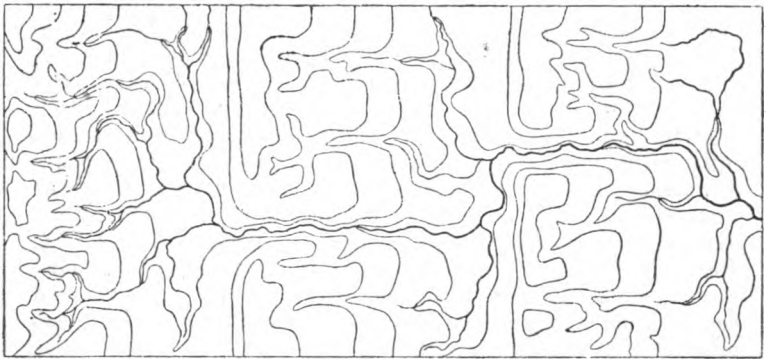

FIG. 69.—Alternation of Weak and Strong Tilted Rocks.

FIG. 70.

ridges and of the river at the defiles. He would then be able with a limited number of intersected points to represent very quickly the essentials of the topography.

341. The surface developed by similar processes acting upon stratified rocks which lie in gentle folds is illustrated by Fig. 71 and Plates XXVI and XXVII. Plate XXVI is part of the map of Northern Sinai referred to above, Art. 336. Fig. 71 is a block diagram drawn from the map of Plate XXVI, looking from S.W. towards N.E. and cut in two parts along the line A—B. It shows that the probable geological structure is that of a "dome," *i.e.*, a short up-fold or anticline in which the folding is greatest in the middle. The part originally highest has been removed by erosion, leaving an encircling scarped ridge with the escarpment facing inwards. In this case several minor features are due to the aridity of the climate in Sinai, but the main features recur on similar structures all over the world, and an example on a larger scale is provided by the Weald of S.E. England.

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Plate XXVII is from an oblique air photograph taken in Persia and shows a "hogsback" which has not yet been scooped out to the extent of that above illustrated.

342. *Influence of Climate on Rocks of Similar Structure.*—It is important to note that similar rocks in different climates will give rise to different topographical types. Thus, a weak rock, such as clay where the climate is damp, as in England, is characterized by a surface (Plate XXVIII) of well-rounded hills and hollows, and in spite of the humidity running streams are rather far apart. These features are accounted for by the thick soil and vegetation. In contrast is the topography developed on similar weak rock in an arid climate, Plate XXIX. Here the "texture" of the country is much closer, *i.e.*, there are more stream lines in a given area, slopes are steeper and contours much less regular. In such country there is little soil or vegetation to retard erosion or to concentrate the surface water into a few important streams.

343. *Agents of Erosion.*—As indicated in the beginning of the chapter the keynote of the land forms is often given not by the kind of rocks underlying the surface nor by its altitude, but by the nature of the agents which have eroded the surface. Thus, the clearly outstanding difference between the mountain forms illustrated in Plates XXX and XXXI is due to the fact that the features in the first area have been carved by the normal processes of weathering and running water, whereas those of the second area have been largely moulded by moving ice. In each case portions of a main mountain crest are shown and the river basins are comparable in size and general plan. The absolute altitudes of the second range are considerably greater, but relative heights do not differ much. Each map gives a good example of contour drawing in a mountainous country.

In the first area (Plate XXX) the principal feature to note is the similarity of valley forms throughout. If profiles be drawn to scale across a number of valleys, the resulting sections will differ but little save in size. In no case will they vary much from the form of a widely open V. If longitudinal profiles be drawn along a number of stream lines from source to mouth, they will be found to differ considerably in steepness, but they will all have a uniform characteristic—that the curves become gradually steeper towards the sources of the streams. These are features which may always be looked for in mountain regions whose surface has been moulded by weathering and running water.

In the second area (Plate XXXI) we note, first, that river valleys are much fewer, and that on the gentler slopes there are a number of small lakes which apparently have little to do with the drainage system; secondly, that the basin is rimmed by a series of widely curving ridges, all of them being narrow and very steep. If profiles be drawn as before, many of the cross sections will be steep in their highest and lowest sections and gently

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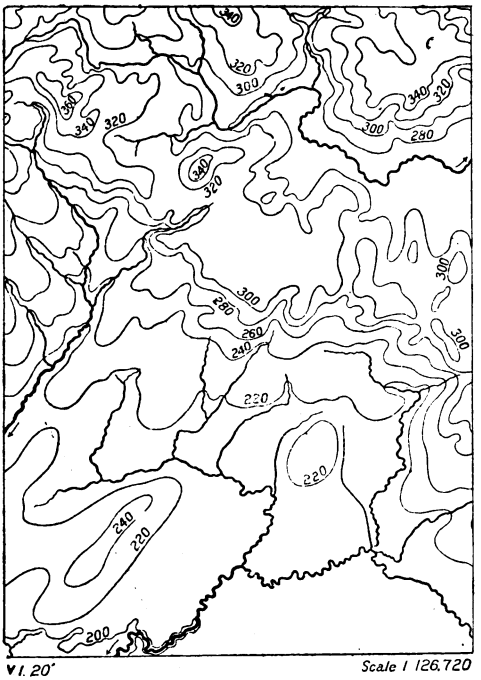

PLATE XXVIII.

Erosion of Weak Formation in England.

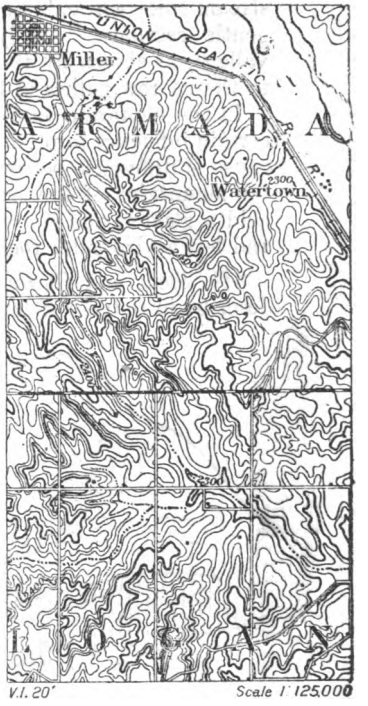

PLATE XXIX.

Erosion of Weak Formation in Nebraska.

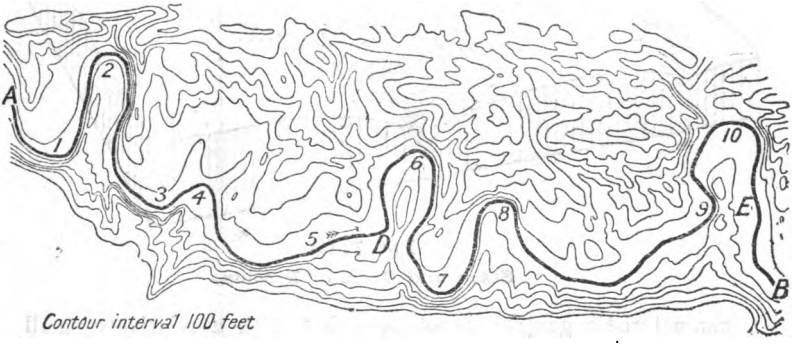

PLATE XXXII.

Meanders of River.

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sloping in the middle, while some of the longitudinal profiles along stream lines will exhibit more than one alternation of steep and gentle sections. Lastly, the smooth rounded heads of the valleys, as shown by the higher contours, are in strong contrast to the narrow gullies of the first areas.

In the mountain area illustrated the rock-structure has had a certain influence in producing the features noted, but the primary cause of difference between the two areas is the past glaciation of the mountains of the second region. Each round-headed valley held a glacier, and the ice has moulded the smooth, steep spurs, and left an irregular rocky bed to contain the numerous lakes.

344. *Stage and Cycles of Erosion.*—It is unnecessary here to describe in detail the land surfaces typical of "youth" with its

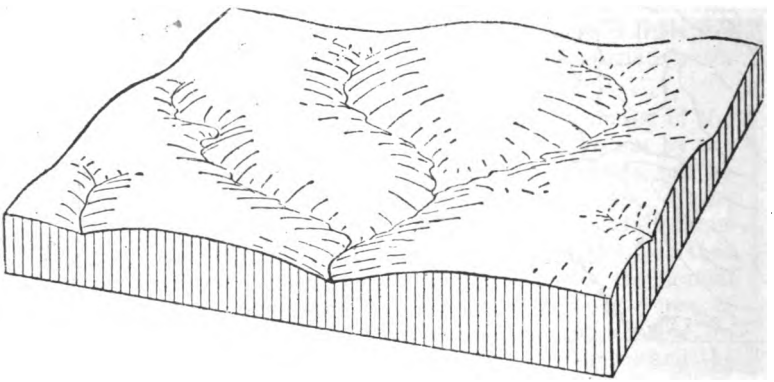

FIG. 72 (*a*)

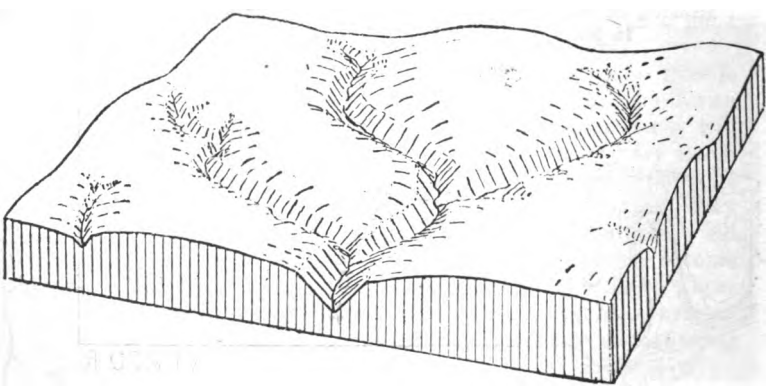

FIG. 72 (*b*)

Stage and Cycle of Erosion.

characteristic general smoothness, but with a relatively small number of deep narrow valleys, through "maturity" with its maximum dissection, and greater amount of relief, complex,

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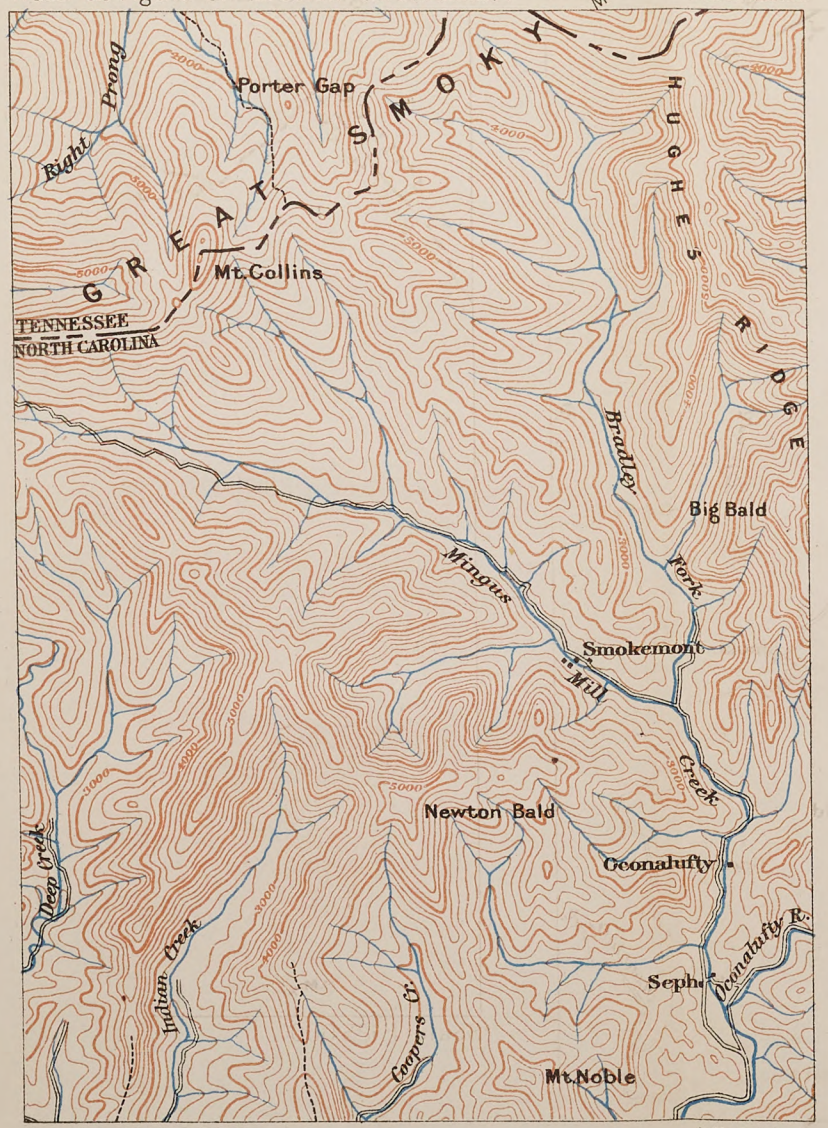
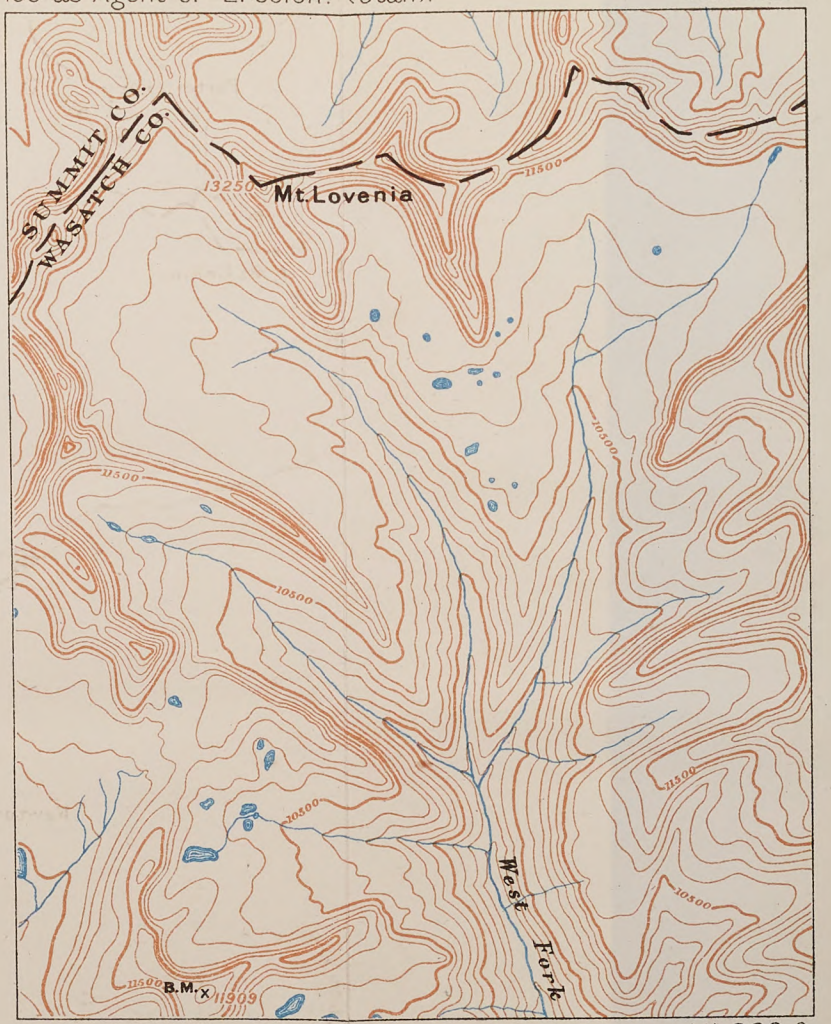
Water as Agent of Erosion (N. Carolina). Plate XXX



Scale 1:125,000. V.I. 200 ft.

Ice as Agent of Erosion. (Utah). Plate XXXI



Scale 1:125,000. V.I. 200 ft.

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dendritic arrangement in plan of the stream-lines, &c., to "old age" and its return to relative smoothness, low relief, and sluggish meandering streams. These are features which the topographer will do well to study. But there is one aspect of the principle of cycles of erosion which he cannot afford to neglect. It is that a break in the cycle is always marked by a clear change of slope which runs through the entire land surface affected.

The recognition of this feature and the fact that it does not occur haphazard, but bears a close relationship to the general profile of the valleys will add greatly to the expression of the map as well as to its practical value. Fig. 72 (*a*) shows a surface which has reached a rather advanced stage of development. But before the cycle could be completed in this case an earth movement of some sort such as a broad uplift has enabled the streams to renew their cutting activity, thus initiating a new cycle of erosion. Fig. 72 (*b*) shows an early stage in the new cycle. The old gentler slopes now meet the new steeper slopes in a well-marked edge which runs up all valleys and maintains a height above the stream generally increasing with the size of the stream. The topographer having once identified this characteristic change of slope in a region will be certain to find it recurring with but little regard to rock structure throughout a considerable stretch of country.

345. *Expressive Form-lining.*—While it is impossible here to give examples of contours expressing any great variety of typical land forms it will be useful to utter a word of warning regarding the sketching of topographic forms in general. Whatever be the cause producing particular forms it is nearly always true to say that they are not to be faithfully represented by uniformly graceful curves, while it is equally true that straight lines and sharp angles will not give the necessary portrait. It is best to consider land features, when sketching their contours, as solid polyhedra with irregularly curved sides, and unless there is good reason for departing from the rule, crests of spurs will be represented by contours bending rather sharply on the crest in such manner that the eye in reading the map has no difficulty in supplying the continuous ridge-line. Similarly the expression of the map is greatly helped by the careful drawing of contours so that one bends in sympathy with the next.

Figs. 73 (*a*), (*b*), and (*c*) illustrate a piece of country mapped without expression by the "graceful curve" method (*a*), by form-lines showing unnatural regularity (*b*), and with expression (*c*).

346. *River Erosion.*—Meandering rivers form such a common feature of land surfaces that their relation to the topography must be specially noted.

A river moving freely on a smooth alluvial plain, Fig. 75 (*a*), deposits material on the banks in times of high flood and so builds these up to a level somewhat higher than that of the plain. This feature, often so important in marshy country, will be repre-

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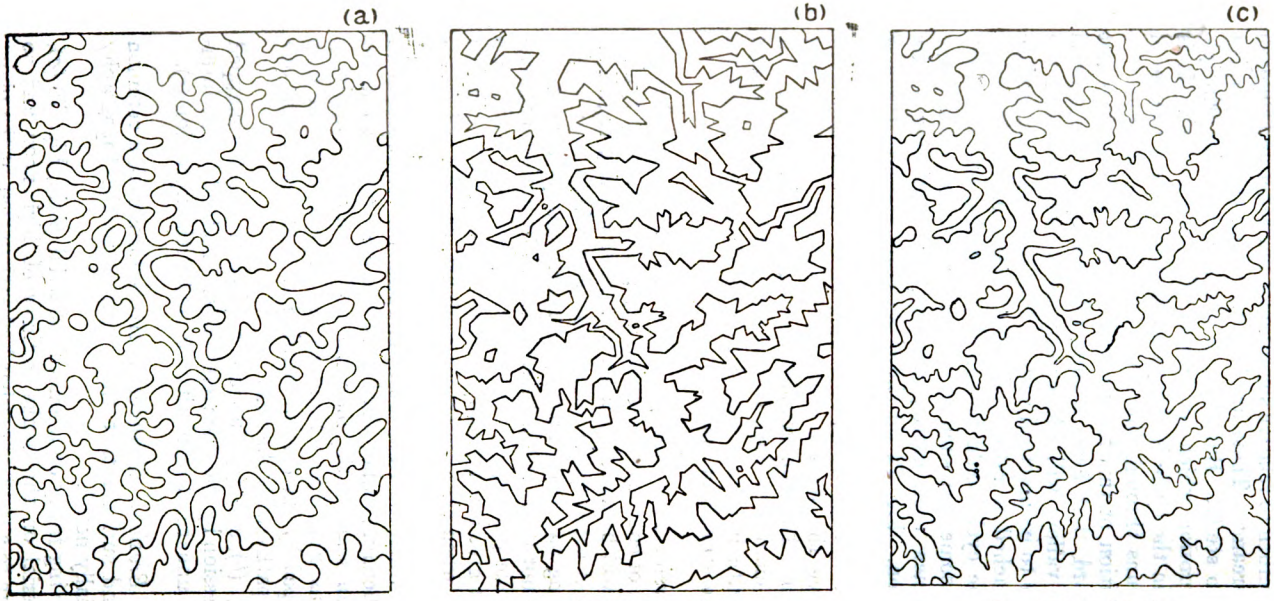

FIG. 73.

Three Styles of Form-lining (Cross Plains Quadrangle, Wisconsin).

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sented on a map by a contour outlining the raised area on both banks (Fig. 74). Free meanders of this character change their shape and position very quickly. Where an uplift of the land

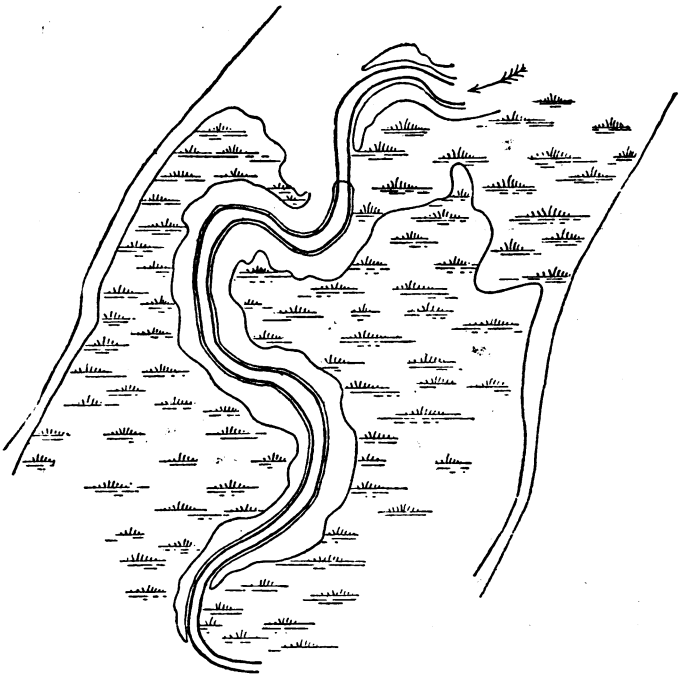

FIG. 74.

River in Marshy Plain.

takes place such a river gradually incises its bed, thus producing a narrow winding gorge. In these incised meandering valleys the power of the stream to erode its banks is not uniform, but is greatest on the down-stream sides of loops and on the outer bank of each loop. By this process the meanders gradually change their position, moving down stream and truncating the spurs. The spurs tend to have the stream at their foot on the up-stream side, which is the steeper. On the down-stream side they are edged by "scrolls" of flood plain. Figs. 75 (*a*), (*b*) and (*c*) illustrate three stages in this development. Plate XXXII shows a map of an actual valley in which the river flowing from A to B has incised its bed in a plateau to the depth of some 600 feet. The loops have been numbered from 1 to 10. The meanders seem to be moving in the manner described above, but the stage is not quite so advanced as that shown in Fig. 75 (*c*), and the contours about meanders 1–2 and 7–8 mark highly

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typical forms. The meanders numbered 5 and 9 have for some reason concentrated erosion at D and E, and it appears likely

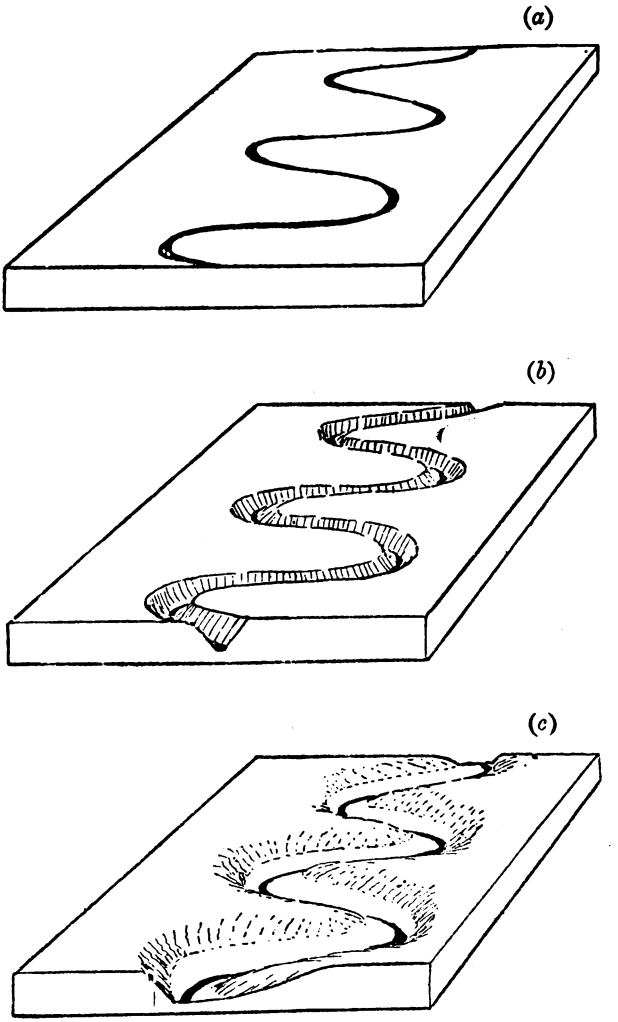

FIG. 75.

Three Stages of River Erosion.

that these necks will be severed and the meanders numbered 6 and 10 be cut off.

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Appendix IV.

SPELLING OF PLACE NAMES.

§90. Spelling and Transliteration.

347. *Spelling.*—There is no geographical subject which has given rise to more discussion and to greater differences of opinion than that of the spelling of names, and it is desirable that officers should have some acquaintance with the principles involved. It is a matter which affects not only maps, but also official reports and handbooks.

When a country uses the Roman characters there is no difficulty. Clearly the name must be spelt as in the country of origin unless there is an anglicized form in common use, *e.g.*, Florence for Firenze, in which case the form adopted would be a matter for consideration in each case. The question of transliteration does not arise.

348. *Transliteration.*—When, however, a language does not use the Roman character the names must be transliterated for English use. Such languages are Russian, Serbian, Bulgarian which use the Cyrillic character, Turkish and Arabic which use the Arabic character, Greek, Chinese, Japanese, and many other Eastern languages. In Russian, Turkish, Arabic and Greek it is possible to prepare tables showing how each letter should be transliterated so that an Englishman should pronounce the word in its new form as nearly as possible as it is pronounced in the country of origin.

Whatever system of transliteration is used it is evident that only a small measure of success can be obtained. The letters do not, as a rule, correspond exactly with the English letters; and even if they did, the fact that there may be several different ways of pronouncing the same letter would make a perfect representation of the sound impossible. It is easy to see that the transliteration, letter by letter, of the English words *through*, *though*, and *tough*, would give a foreigner no guide to the pronunciation of more than one of them.

349. *Principles of Transliteration.*—For better or worse, however, names have to be transliterated, and rules for doing so have to be devised. These fall into two parts :—

(*a*) The sounds to be attributed to each letter of the English alphabet must be laid down and adhered to for the transliteration of all languages.

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(*b*) A table has to be drawn up for each language, which it is desired to transliterate, showing what letters of the English alphabet, employed as in (*a*), are to be used for each letter of the foreign alphabet in question.

For (*a*) a new set of rules has recently been drawn up by a Committee of the Royal Geographical Society on which the War Office and several other Government departments are represented. It is printed below. It differs but little from the Knox rules which have been followed for many years by the Geographical Section of the General Staff, which themselves were almost identical with the old rules of the Royal Geographical Society, based on the Washington system of the Admiralty.

§91. R.G.S. II. System, 1921.

350. *Rules for the Spelling of Geographical Names for British Official Use.*

(1) The spelling of every place-name in an independent country or self-governing dominion using the Latin alphabet* shall be that adopted by the country or dominion, except in the case in which certain important localities have also, in addition to the official name, another customary name, notably different, in which case the name customary in British use (*i.e.*, " conventional ") may be adopted (*e.g.*, Geneva, Warsaw, &c., for Genève, Warszawa, &c.).

(2) The spelling of such place-names in colonial possessions as belong to languages coming under Rule (1) will be spelt in accordance with that rule.

(3) The accents and diacritical marks in official use by the above countries will be retained. Wherever it appears desirable, the pronunciation will be shown by giving the name as transliterated on the system below.

(4) All other place-names throughout the world will (with the exception of " conventional " names and some others) be spelled in general accordance with the following system.

The broad features of this system are—

(*a*) That vowels are pronounced as in Italian and consonants as in English ;

(*b*) That every letter is pronounced, and no redundant letters are used.

The system aims at giving a close approximation to the *local* pronunciation ; but it is recognized that in some languages, notably Russian, Greek, and Arabic, the necessity for letter-for-letter transliteration often renders this impossible.

* Including " Latin " alphabets containing extra or modified letters, such as Serbo-Croatian, Polish, Rumanian, &c. The pronunciation of these letters is given in the " Alphabets of Foreign Languages," &c., mentioned below.

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Table of Spelling and Pronunciation, R.G.S. II.

a	Long and short, as in *lāvă*	Somāli, Bokhāră.*
ä	As in *fat*; rare except in Teutonic languages.	
ai†	The sound of the two Italian vowels; frequently slurred over, almost as in Eng. *aisle, ice*	Wadai; Shanghai.
au	The two Italian vowels; frequently slurred, almost as *ou* in *out*	Sakau; Bauchi.
aw	When followed by a consonant, or when terminal, as in *awl, law*	Dawna, Saginaw.
b	As in English.	
c	Not to be used, but always replaced by *k* or *s*; except in the compound *ch*, and in many conventionally spelt words, as	Kandahar, Seram. Calcutta, Celébes.
ch	As in *church*; never *tch* or *tsch* for this sound	Chad, Naroch.
d†‡	As in English.	
dh	Soft *th* as in *they*; a slight *d* sound sometimes preceding it in Semitic languages	Dhuvu; Riyadh.
e†	Long as in *eh ?*; short as in *bet.* (For the *e* sound in the French *je*, see note at end on the "neutral vowel")	Gēlo; Mafĕking.*
ei†	The two Italian vowels, frequently slurred	Beirut, Raheita.
(eu)	Not used as a single sound.	
f	As in English; *ph* must not be used for this sound (except in Greek; see *ph*)	Mustafa, Haifong.
g	Hard, as in *get, gift*; never as in *gem, gin*	Gedáref, Gilgit.
gh	Soft guttural, the Arabic *ghain* (غ)	Dagh, Baghdad.
h	Used only when sounded; or in the compounds *ch, dh, gh, kh, sh, th, zh*	Ahmadabad, Vrh.
i	Long as in *marine*; short as in *piano* (not as in *pin*)	Fījī; Kībonde.*
j	As in English; except in transliteration of Russian, Bulgarian, and Chinese, where it equals *zh*, or the French *j* §	Juba, Ujiji (Eng. *j*); but Jitómir, Jelĕzna, Jao-ping (Fr. *j*).
k	As in English: hard *c* should never be used (except in conventionally spelt words)—thus, not Corea, but	Korea.
kh	Hard aspirated guttural, as in the Scottish *loch* (not as in *lock*)	Khan, Sebkha.
l‡ m n‡	As in English.	
ng	Has three separate sounds, as in *engrave, finger*, and *singer*. If necessary to distinguish, in the first and third forms a hyphen may be placed, as *en-grave, sing-er*	In-gássana; Bongo; Ng-ami, Tong-a.

* The long and short symbols given here are merely for explanation, not for use.

† Pronounced differently in Greek: *see* "Alphabets of Foreign Languages transcribed into the R.G.S. II. System" (to be published by the Royal Geographical Society).

‡ *See* note at end on *Liquid Sounds.*

§ This decision has been arrived at owing to the large number of English (and French) maps of these countries in which the *zh* sound appears as *j*.

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o	Long as in *both** ; short as in *rotund*	Angōla, Kigōma : Angŏra, Hŏnŏlulu.†
ö	As in German ; equals the French *eu* in *peu* ; or nearly the English sound in *fur*	Gömle, Yeniköi.
oi‡	The Italian vowels ; sometimes slurred as in *oil*. If necessary for pronunciation, a hyphen may be inserted	Hanoi.
ou‡	Dissyllabic, and not as French or English *ou*....	Zlatoust.
ow	Represents, as a diphthong, nearly the *au* sound (above) *only* in the romanization of Chinese. Conventional	Hankow.
p	As in English.	
ph	As in *loophole* ; not to be used for the *f*-sound, except in Greek	Chemulpho ; Paphos.
q	Represents *only* the Arabic Qaf (ق) : *i.e.* a guttural *k*	Qena, Iraq.
qu	Should never be employed to represent the sound of *kw* : thus, not Namaqua, Quorra, but	Namakwa, Kworra.
r §	As in English ; should be distinctly pronounced.	
s	As English *ss* in *boss*, not as in *these* or *pleasure*.	
sch	As in *discharge*, the *s* distinct from *ch*	Ruschuk.
sh t §	As in English.	
th	Hard *th* as in *thick*, not as in *this*	Tharmida.
tth	The first *t* pronounced separately from the *th*, as in *at the*.	
u	Long as in *rude*, or as *oo* in boot ; short as in *pull*	Zūlū ; Rŭanda.*
ü	Represents the French *u*, as in *tu* (Fr.)	Üsküb.
v w x	As in English.	
y‡	Always a consonant, as in *yard* ; it should not be used as a terminal vowel, *e* or *i* being substituted ; *e.g.* not Kwaly or Wady, but	Kikuyu, Maya. Kwale, Wadi.
z	As in English *gaze*, not as in *azure*.	
zh	As the *s* in *treasure*, the *z* in *azure*, or the French *j* in *je* ; but for the sound in Russian, Bulgarian, and Chinese use *j* (*vide* note above under *j*)	Zhob, Azhdaha.

NOTES.

The doubling of a vowel or a consonant is only necessary when there is a distinct repetition of the single sound, and should otherwise be avoided	Nuuhia, Oosima, Jidda, Muhammad.

* The true Italian ō is broader than this : almost as in *broth*.

† The long and short symbols given here are merely for explanation, not for use.

‡ Pronounced differently in Greek : *see* "Alphabets of Foreign Languages transcribed into the R.G.S. II. System" (to be published by the Royal Geographical Society).

§ *See* note at end on *Liquid Sounds*.

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Accents should not generally be employed; but in order to indicate or emphasize the stress, an acute accent may be used.	Saráwak, Qántara, Tong-atábu, Paraná.
A long or short mark over a vowel (*e.g.* ā, ŏ) should only be used (and that sparingly) when without it there would be danger of mispronunciation	Kūt, Hashīn
Hyphens will not be used except to indicate pronunciation	Mus-hil.

Liquid Sounds.—The occasional "liquid" or "palatalized" sound of *d, l, n, r, t,* &c. as in *d'you, lure, new, clarion, tune,* &c.) is as a rule sufficiently represented by a following *y*; where, however, owing to a following consonant, or to the letter in question coming at the end of a word, the *y* is inapplicable, the liquid sound will be represented by an apostrophe, thus: *d', l, n, r, t',* &c.

The "Neutral Vowel."—The "indeterminate" or "neutral" vowel sound (*er*), *i.e.*, the sound of *a* in *marine*, *e* in *often*, *i* in *stir*, *io* in *nation*, *o* in *connect*, *ou* in *curious*, *u* in *difficult*, &c., *e* in French *je*, or the often unwritten vowel (*ʾ Fat-ha*), in Arabic, &c., is represented as a rule by *a*: as in Basra, Hawiya; but sometimes by *e*, when the sound approximates more to *e* than to *a*: as Meshed, El Gezira.

(In any guide to pronunciation issued by the Permanent Committee on Geographical Names, the "neutral vowel" is represented generally by the italic *e*: occasionally also by italic *a* or *u*.)

This sound must not be confused with *e-mute*, where the *e* is not sounded at all: as in Abbeville.

§92. Individual Languages.

351. *Special Rules for Certain Languages.*—It is hoped that in future the system given above will be universal. Even if space permitted it would not be necessary to print here the transliteration tables for each language. The R.G.S. Committee is preparing such tables for many languages, but it is too much to hope that they will be universally adopted. The surveys of India and Egypt have their own systems for transliterating, and any change of system would involve many alterations in existing maps.

Although the use of these rules and tables involves a transliteration letter by letter which is designed to give the best approximation possible to the pronunciation, an expert in both languages will constantly be aware that the transliterated form does not represent the sound, and may feel tempted to improve on it; but usually the results must be accepted.

352. *Unwritten Languages.*—The pronunciation table printed above is equally essential for arriving at a suitable form of spelling names in unwritten languages, such as those in tropical Africa or the Pacific. Here sound is the only guide and the object aimed at is to represent the name so that it will be pronounced correctly by an Englishman. It is evident that no system of transliteration will enable a name to be correctly pronounced by people of different nationalities.

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353. *Chinese and Japanese.*—It is very desirable that officers to whose lot it falls to ascertain by word of mouth and to record names should follow the rules here given. Certain languages require special treatment. For instance, Japanese and Chinese are written languages but have no alphabet. It is therefore necessary either to treat them as unwritten languages and be guided by sound only, or to prepare elaborate tables giving the Roman lettering, to be used for each syllable or symbol. This was done for Chinese by Sir T. Wade, and his system has been that most generally used ever since. The Post Office has a system of its own which is being gradually extended with the spread of postal facilities. It is probable that in the course of time the Post Office system will be universal, but for the present the Wade is used by the War Office. The Post Office follows the Wade system as far as possible, but is guided chiefly by local pronunciations; the Committee on Geographical Names propose to follow the Post Office as closely as possible.

A similar system has been prepared for Japanese by Mr. Hepburn; but the Japanese publish maps giving the names in Roman lettering, and these would presumably be accepted. Greek also has to be specially treated, for the Greek alphabet is so familiar that it is usually more useful to be able to recognize the original letters than to put the name into a strange form even if that form gives the correct pronunciation. Thus the letter ϕ is always transliterated by *ph* and not by *f*.

354. *Double Transliteration.*—Many other difficulties arise. For instance, a name of Russian origin may appear on a map transliterated into German. To get it in its correct form by our rules it would be necessary to put it back into Russian and then transliterate it afresh. Native names in Africa and elsewhere are transliterated by other Powers according to their own rules and pronunciation, and a fresh transliteration is required for an English map. Examples are :—

English.	*French.*	*German.*	*Local Spelling.*
Cherkasi	Tcherkasy	Tscherkassy	Cherkasi (Russ.).
Kharkof	Kharkov	Cherkow	Xarkov (Russ.).
Nikolaef	Nikolaiev	Nicolajew	Nikolaeb (Russ.).
Cyprus	Chypre	Cypern	Kypros (Gr.).
Mecca*	Mecque	Mekka	Mekka (Arab.).
Jidda	Jedda	Djidde	Jidda (Arab.).
Muscat*	Muscate	Muskat	Masqat (Arab.).
Wadi	Ouad	Wadi	Wadi (Arab.).
Morocco*	Maroc	Marokka	
Kilimanjaro	Kilimandjaro	Kilimandscharo	
Nyambane			Inhambane (Port.).
Machiche			Maxixe (Port.).

* Conventional.

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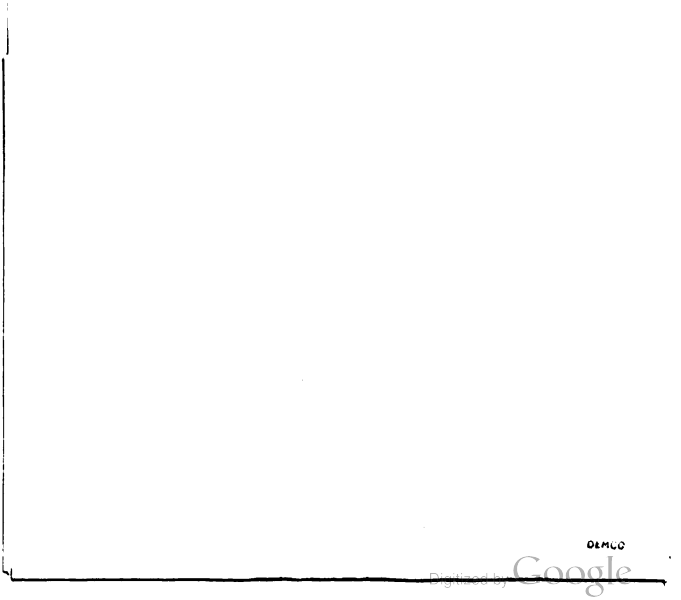

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